THE ANNALS OF APPLIED BIOLOGY

THE OFFICIAL ORGAN OF THE ASSOCIATION
OF ECONOMIC BIOLOGISTS

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EDITORIAL.

THE Association of Economic Biologists was founded ten years ago and commences herewith the publication of a journal devoted to the special interests of its members. During this period its scope has broadened and the *Annals of Applied Biology* is intended to cover the ground in applied biology which is not now covered by special journals such as those dealing with agricultural science, parasitology, genetics and medical science.

Whilst the membership of the Association includes those who contribute to these special journals, it is now intended to deal especially with other branches of applied biology, and we are glad to be able to issue in our first number a wide range of papers, which will soon become still wider.

All papers which bear on the scientific problems of applied biology will be welcome; we have no place for purely systematic work which is amply provided for elsewhere, nor for faunistic work as such.

The Association. The Association was founded in 1904 with headquarters in Birmingham and has since held meetings at which papers on biological subjects were read and discussed. The headquarters are now in London, and it is hoped to hold meetings quarterly, usually in London, but with one meeting annually elsewhere.

There is room for a wider membership in the Association, which aims at drawing together workers in applied biology, and if that membership can include a large majority of those engaged in research and teaching, and those in official positions, the influence of the Association could be applied both to public opinion and to national affairs in a measure wholly impossible in the past.

We hope to secure the support of workers in the Dominions and Colonies. Few people realise how great is the progress made in applied biology in the Over-seas Dominions during the last twenty years and how vital to the success of all tropical industries is the work that is being done in applied biology ; it has become evident in regard to medicine, but is less realised in agriculture, horticulture, animal breeding, and other industries in which investors at home are interested ; nevertheless, such industries depend for their continued prosperity more and more on research in biology and the application of its results.

The Association will attempt to form a link between workers in Great Britain and in the Dominions, and the support of colonial members of the Association is as vital to success as that of their fellow-workers in this country.

Towards effecting this, the publication of a journal may have a great influence and we hope to attract not only the more solid scientific contributions but also notes of progress, of interesting achievements, of practical problems, as they present themselves to members in the various parts of the Empire.

We have lately made a wide appeal for membership, since we believe that only by organisation will the applied biologist be in a position to establish his subject as one of profound importance in the future welfare of the Empire. The recognition of the important part played by biology is as yet very imperfect, even in the minds of the most advanced officials of State Departments and Colonial Administrations ; large problems, in which technical knowledge is required, are settled without the technical expert being seriously consulted and this is the fault, not of the official mind or of the man-in-the-street's attitude, but of the applied biologists themselves. Medical men are organised and that so successfully that in a present problem, largely entomological, the medical interest has tended to prevent all recognition of the value and need of the entomologist's services ; we refer to the tse-tse fly problem in Africa but we could quote other similar cases ; at the recent Phytopathological Congress in Rome the technical experts were outnumbered by the diplomats and no country had been able to give its experts a deciding voice in the Congress, though the questions involved were admittedly technical and could be decided only by experts.

We see this attitude daily and every biologist in the Empire suffers from this sooner or later ; it was once a custom in India to appoint a medical officer to any scientific post, simply because science was so vague a conception to the senior official, educated in the classics, that

he could not conceive subdivisions of science requiring technical expert advice: that day is gone in India but there is still much to teach the official, as also the man in the street, in this respect.

If then the applied biologist is to make himself felt, it will be through an organisation comparable to those by which the chemists, the engineers and the doctors assert themselves; we hope to make the Association such an organised body: the publication of the *Annals* will be a means to that end and we ask all applied biologists to support it, to join the Association and to induce others to do so too.

The Library. There is at present no centre in London where the literature of applied biology can be consulted or obtained on loan. Societies such as the Zoological, Entomological, and Linnaean, maintain libraries of systematic and purely scientific literature, but scarcely any at all of the applied aspect. It is proposed to found the nucleus of a library of applied biology and in this connection an appeal is made to members to send:

(1) Separates of all papers they have published so far as these are available.

(2) Separates of those they have received which they do not specially want and duplicates.

(3) Parts or sets of any periodicals they do not need.

(4) Books they can spare.

This is an experiment in this sense, that it is not yet certain that the library can be maintained; but members are asked to send separates, etc. under these conditions:

(1) All will be acknowledged.

(2) All will be kept in a room at the Royal College of Science, open to all members.

(3) All will be card-indexed under author and subject.

(4) All will be registered with the name of the lender and under the condition that, should the library be broken up or not maintained, they will be returned to the lender.

(5) So far as possible, they will be available for loan, personally or by post, on the borrower signing a receipt, and an undertaking to return them or be liable for their return or replacement.

(6) The Association will pay postage out, the borrower postage back.

It is probable that the foundation of a library will be of the greatest value to members, and when the membership has increased the income of the Association will enable the library to be added to and made of

greater value. In the present venture, no expenditure is entailed on the Association beyond postage; the whole library will be, for the present, on loan, but when it becomes possible, the Association will establish a permanent library and ask all lenders to definitely donate or resume their contributions. A library fund has been established to which contributions of any amount are invited.

Meetings. Members resident in the United Kingdom are reminded that the meetings will now be quarterly and before this appears the first will have been held.

Members are informed that it is proposed to have the next meeting after the International Agricultural Conference in London, which ends about June 30th. We hope that all members home from the Colonies or India will attend; the library room kindly lent us by the Imperial College of Science, South Kensington, is available for members and contains the present small nucleus of our library.

H. MAXWELL-LEFROY.

IMPENDING DEVELOPMENTS IN AGRICULTURAL ZOOLOGY.

By Professor F. W. GAMBLE, F.R.S.

The endowment of research in Agricultural Zoology by the Development Commissioners is a sign of the increased interest in the possibilities of the application of this subject to actual practice. Hitherto entomology only has been considered of value in regard to agriculture and though other classes of animals have long been known to exert an important influence upon the yield of crops and stock, yet no advance has hitherto been made in their study which can compare with that accomplished in the case of insects. Now however the Board of Agriculture has asked the University of Birmingham to take up these hitherto neglected branches of zoological study with special reference to helminthology and a beginning has been made both with this subject and with the protozoology of the soils.

In the present article I propose to discuss briefly some of the problems that lie before the investigators in this latest application of zoology to agriculture. Taking first, the organisms of soils (other than insects) the primary impression is the need for an ordered body of systematic knowledge such as entomologists already possess in virtue of the longer study and larger number of devotees which this subject has attracted. There has been up to the present no concerted attempt in any country to determine the biological factors of the soil, their relations to its qualities, to seasonal changes, or to its fertility. Efforts have been made at the Rothamsted Laboratory and elsewhere to determine the effects of certain protozoa ; and in Italy a movement for the study of soil organisms is in its inception. But we have at present no estimate based on any but exceedingly small samples, of the animal factors, estimated either qualitatively or quantitatively, that are present in the soil. Dr Russell and Dr Hutchinson have brought forward evidence that the factor limiting the accumulation of one or more of the essential substances for plant production is a biological and not a chemical one.

And Mr Goodey, working at first on their samples and more recently at the new Birmingham Station, has determined the protozoan fauna of certain small samples of soil, the properties of which have been tested in other ways at the Rothamsted Station. By these and other allied observations carried out by C. H. Martin and Lewin in this country and by A. Cunningham in Germany, it appears that a rich fauna of ciliate, flagellate, and amoeboid protozoa are present in certain soils ; that some of them at least are capable of active life therein under ordinary conditions ; and that they are to be seen, when raised in cultures, ingesting masses of bacteria. Much work however still remains to be done on these organisms both from the purely zoological aspect and from the point of view of their effect upon soil fertility, and inasmuch as sound results on the life-history of protozoa involve concentrated study continued over a long period, it would be idle to expect a rapid advance in such a difficult field of research. There can be no doubt however that the results will be of great interest both to the science and practice of husbandry.

Another branch of soil science which is being promoted at Birmingham University relates to the free-living Nematodes and to those of parasitic or saprophytic tendencies.

That these play an important part in soil metabolism and in the germination and growth of crops can hardly be doubted, but no data are as yet forthcoming except for those essential parasitic species of *Tylenchus* and *Heterodera* that occur sporadically on various cereals and vegetables.

The case of the recent serious outbreak of disease in the rice fields of Bengal shows how important the study of these eelworms may prove. The rice-plant in certain districts dies off in patches or the crop may fail altogether from the attack of Ufra disease. This term " Ufra " meaning " from above " suggests that the blight is due to atmospheric conditions, but an investigation conducted by the Agricultural Research Institute at Pusa (Bulletin No. 34, 1913, *Diseases of Rice* by E. J. Butler, M.B.) has shown that the main cause of " Ufra " is not atmospheric but is a small Nematode, *Tylenchus angustus*, which by injuring the epidermis of the unprotected parts of the rice-shoot causes weakening, discolouration and ultimately the death of the plant. Moreover as this worm multiplies rapidly and swims through the muddy fields from one plant to another, a single focus of infection may spread over a considerable area in a short time. The serious nature of the outbreak lies in the proximity of the infected district to the great rice-producing countries

in Northern India. On the west of this district at the head of the Bay of Bengal, lie the extensive paddy fields of the Province, whilst on the east is the great export rice-growing tract of the Irrawaddy Delta. The investigation has been conducted chiefly by Dr Butler the mycologist at Pusa, but it is to be hoped that the Indian Government will realise the importance of having a trained helminthologist to prevent the extension of what is perhaps the most serious blow that could befall an oriental peasantry—the loss of the paddy crop.

There is however no need to go so far afield as India to illustrate the importance of research on soil Nematodes, and Mr Gilbert E. Johnson, M.Sc. of Birmingham University, who is taking up this group, has already shown by his interesting paper on unisexual families in the Nematode parasitic in the earthworm (*Quart. Journ. Micr. Sci.* June 1913) that there are many purely scientific as well as applied questions upon which the study of Nematodes throws light.

The part played by earthworms in regard to soil problems and plant rearing has been very inadequately ascertained, and in this subject further advances may be confidently expected. Enumeration of the earthworm fauna has proceeded apace in this country of late, chiefly through the enterprise of the Rev. Hilderic Friend and collectors inspired by him. The result has been a marked increase in the known micro-forms or Enchytreids, whilst a careful descriptive account of the structure of *Enchytreus pellucidus* by Mr H. H. Stirrup, M.Sc. (*Proc. Zool. Soc.* 1913) has added much needed anatomical evidence on certain points though it leaves the important question of the eggs and their mode of deposition unsettled. What is wanted, however, more than anything else with regard to this group, is an estimate of its effect upon plants and soils.

Coming now to the parasitic helminths, there has been a great increase in recent work carried on chiefly by Dr Shipley and members of the Grouse Commission in this country, in America, Germany, Italy, and France. This has confined itself largely to systematic and anatomical features and there is a great deal still to be made out with regard to the life-histories of even the commoner Nematodes and Platyelmia, whilst curative or preventive measures are as yet in their infancy. Farm stock, poultry and game in most countries are more commonly infected with these verminous parasites than is generally supposed. The farmer may know the fact well enough and he often finds a cheap and effective method of ridding his stock of these pests by the application of a vermifuge in early autumn ; but it is not always that his stock

responds to this curative treatment, and although evidence is at present hard to obtain except by personal visits, yet it points to the serious incidence of husk and other round worm diseases in certain districts, whilst the severe stomach worm disease seems at present to be waning in extent of range and intensity. There is however a very real need of dealing more fully with these animal parasites from all points of view than has ever been undertaken before and to this end the Board of Agriculture has approved the appointment of Dr Chas. L. Boulenger as Reader in Helminthology at Birmingham University. It is to be hoped that the other centres, such as Liverpool and London Universities where similar work is organised and other Research Institutions where animal nutrition and animal pathology are dealt with, will co-operate with Birmingham in regard to the difficult common problems that arise in connection with prevention of stock from these verminous diseases.

One general conclusion is reached on considering the future that lies before zoological research as applied to agriculture. It is that mutual assistance between the man on the land and the worker in the laboratory or in the field is essential to progress. We need a careful census of the country, a census that is of the animals and the animal-borne diseases affecting agriculture. We need more work, far more work, on the life-histories of the groups in question, whether indifferent, noxious or beneficial. But more than these, there is required a real and mutual understanding between the stock owner and the investigators and between the investigators of different countries working at similar problems. An organised study of animal parasites is now in progress in most civilised countries, and renewed interest in the subject has spread like a wave in the last few years. Schools of research are growing up in Egypt, in Australia, Japan and China, so that a means of coordinating the activities of such scattered workers is highly necessary. May this new journal be effective in promoting the progress of research by encouraging such mutual understanding!

THE ACTION OF BORDEAUX MIXTURE ON PLANTS.

By B. T. P. BARKER, M.A., and C. T. GIMINGHAM, F.I.C.

(University of Bristol; Agricultural and Horticultural Research Station.)

In the course of experimental work involved in the investigation of the fungicidal action of Bordeaux mixture[1], a number of observations have been made on the inter-action between the spray fluid and the plants with which it comes into contact in the process of spraying. Further attention has now been given to this part of the subject and as the results help to explain various points arising in practical spraying, it is proposed to give an account of the experiments here.

It will be most convenient to consider the work in two sections, dealing with (*a*) spray injury or "scorching" by Bordeaux mixtures, and (*b*) the penetration of copper from Bordeaux mixtures into the plant.

Foliage Injury or Scorching by Bordeaux mixture.

The injury to foliage, more or less pronounced, which is frequently found to follow the application of Bordeaux mixture, has been the subject of a good deal of work, especially in America. As regards its possible bearing on the question of the *fungicidal action* of Bordeaux mixtures, the matter is discussed shortly in Section II of the second paper referred to. In considering the various means by which copper might be brought into solution on the surface of sprayed leaves, the suggestion was then made that some importance should be attributed to the influence of exudations from injuries to the leaves; and it was further suggested that if soluble copper is produced in this way, it would probably show its presence by causing or intensifying scorching. This point has been followed up in some detail.

In order to have reliable material for experimental work in this

[1] See *Journ. Agric. Sci.* IV, p. 69; *ibid.* IV, p. 76.

connection, it was essential to obtain apple foliage known to be entirely undamaged. As is generally recognised, it is almost impossible to find any number of apple leaves, when grown under ordinary conditions, which are really free from minute injuries of some sort or another. It was therefore found necessary to grow foliage specially protected from liability to injury. With this object, a number of one year old apple seedlings in small pots were carefully cleaned before the leaf buds

1 2

Fig. 1. Foliage undamaged and treated with "no-excess-lime" Bordeaux mixture.
Fig. 2. Foliage damaged with scratches and cuts and sprayed with water.

opened and each one enclosed in a muslin cage supported on a light frame. The plants were kept in a cool greenhouse and the new foliage put out was thus almost completely protected from the chance of damage by bruising or by insect attacks. A few leaves on some of the plants were slightly attacked by apple mildew, but these were always removed before starting an experiment.

When the leaves were fairly well developed, the plants were uncovered and the following series of experiments was carried out:

Plant No. 1. Leaves covered with ordinary Bordeaux mixture (*i.e.* containing large excess of lime).

Plant No. 2. Leaves first artificially damaged with scratches and pin-pricks and then treated as No. 1.

3

4

Fig. 3. Foliage damaged with scratches and cuts and treated with "no-excess-lime" Bordeaux mixture.

Fig. 4. Foliage damaged with pin-pricks and treated with ordinary Bordeaux mixture.

Plant No. 3. Leaves covered with "no-excess-lime" Bordeaux mixture[1].

Plant No. 4. Damaged exactly as No. 2, and the leaves then covered with the "no-excess-lime" mixture.

[1] This expression is used to indicate a mixture of copper sulphate and lime water in such proportions that the whole of the copper is precipitated in the form of the basic sulphate 10 CuO, SO_3 (Pickering).

Plant No. 5. Damaged exactly as No. 2, and then sprayed with water.

On the day following the treatment, there was not the least trace of injury or scorching noticeable on plants Nos. 1 and 3; whereas Nos. 2 and 4 showed very serious injury typical of Bordeaux scorch, and moreover the injuries in every case had quite obviously begun at the artificially damaged spots, and afterwards spread. The scorching was

5 6

Fig. 5. Foliage damaged by aphis and treated with "no-excess-lime" Bordeaux mixture.
Fig. 6. Foliage damaged by bruising and treated with "no-excess-lime" Bordeaux mixture.

very much worse in character and more widespread in No. 4 than in No. 2; No. 5, the plant sprayed with water, showed a browning along the extreme edges of the scratches and spots, but no spreading of injury. Other plants belonging to the same batch as those used in the above trials but which had been allowed to develop their foliage without special protection in the greenhouse were covered with the "no-excess-lime" mixture and included in the series; these showed slight scorching

especially round the edges of the leaves. These results have been confirmed several times.

In another series, aphides were introduced into the muslin cage surrounding the foliage and allowed to increase until many of the leaves were badly infested; the plants thus damaged were then covered with the "no-excess-lime" mixture. The result was very bad scorching, largely confined to the underside of the leaves where they were most damaged by aphis.

The relative degrees of injury under various conditions are shown in the accompanying drawings, the shaded portions representing browning of the leaf.

Similar experiments with the protected foliage of apple shoots standing in water gave confirmatory results. The leaves in this case being much less well developed were mostly entirely killed by the Bordeaux where the artificial damage had been at all severe, but undamaged leaves remained healthy. It was found, further, as was to be expected, that these effects were very much more marked when the Bordeaux was put on soon after the damaging of the leaves. In a moist atmosphere, bad "scorching" followed treatment with the spray fluid up to 24 hours after the damage had been done; if a 48 hour interval was allowed, the effect was markedly less severe and after 72 hours it was very slight. In a fairly dry atmosphere both out of doors and in the greenhouse, the "scorching" following treatment 18–24 hours after the leaves were damaged, was not very serious; although in some cases it got noticeably worse after several days. In these experiments the damage to the leaves was made as far as possible equally by means of pins fixed in a cork, and the spray fluid was usually put on the leaves with a brush so as to ensure a uniform coating.

We have then definite evidence of the importance of the presence of artificially or naturally damaged foliage in considering the scorching by Bordeaux mixture. The extreme difficulty of finding leaves which have altogether escaped damage has already been mentioned; and has been experienced by many other workers. Crandall[1] in America, for example, made a careful examination of 6000 leaves taken at random from 60 different trees and found only 27 (less than 0·5 %) which he could call perfect leaves; although the appearance of the foliage on these trees, on the whole, was good. Wallace[2] in his work on spray injury by lime-sulphur preparations also emphasises the rarity of

[1] *Univ. Illinois Agric. Expt. Sta. Bull.* 135.

[2] *Cornell Univ. Coll. Agric. Bull.* 288.

uninjured leaves, and both he and Crandall and other workers have drawn attention to the fact that, in practice, foliage which is badly attacked by insect or fungus pests or otherwise badly injured is specially liable to serious damage by scorching. Pickering also refers to the effect of injuries in intensifying scorching[1].

There is then no doubt whatever that even slight injuries to the leaf cuticle, if they have not had time to dry up, play an important part in determining the extent of scorching, following spraying with Bordeaux mixtures. Summer foliage, known certainly to be undamaged, as far as our experiments go, shows no scorching.

In order to explain the increased scorching due to leaf injuries, it is necessary to account for the production of copper in a soluble form. Until lately the view has been generally accepted that atmospheric agencies, and in particular carbon dioxide, are responsible for the production of soluble copper sulphate from the insoluble basic copper sulphate which is deposited on the leaf. Both the fungicidal action and the scorching are attributed to the copper sulphate thus formed. It has, however, been shown by one of us[2] that from the chemical standpoint this view is not tenable ; the fungicidal action of Bordeaux mixture cannot be put down to copper sulphate liberated by the action of atmospheric carbon dioxide ; and the experimental evidence for this statement is equally applicable with reference to the scorching action. The authors have further shown[3] that the fungicidal action of Bordeaux mixture is very largely, if not entirely, due to an inter-action between the fungus and the particles of the insoluble basic sulphate with which it comes in contact ; the fungus dissolving and absorbing enough copper to kill itself. In the same way the simplest explanation of the enhanced scorching of damaged, as compared with undamaged, foliage is, that soluble copper compounds[4] are produced by the solvent action of exudations from the injured cells and from those underlying, which are exposed by the injury, and that these substances are then absorbed through the thin-walled cells of the internal tissues of the leaf. It is then easy to understand the gradual spreading of the spots from a centre which is observed in most cases of Bordeaux scorch. Serious scorching occurring several days or even weeks after the actual spraying is probably to be

[1] 11*th Rep. Woburn Exptl. Farm*, p. 123.

[2] *Journ. Agric Sci.* IV, p. 69.

[3] *Ibid.* IV, p. 76.

[4] Soluble copper produced in such manner may, as previously suggested, also act fungicidally.

accounted for by rough weather causing damage to the foliage, or by a serious insect attack. Again the general opinion of practical men[1] that the severity of Bordeaux injury is determined by the weather conditions at the time of spraying and that the injury is most serious when rain immediately follows the spraying fits in well with the view here suggested, since in wet weather any injuries present will heal over much less quickly and will therefore be capable of dissolving copper during a longer period.

In view of these considerations as to the important part played by imjuries to the leaf surface in determining the extent of Bordeaux scorching, it becomes interesting to enquire whether the presence of such injuries is the sole cause or whether Bordeaux mixture does ever cause scorching on *undamaged* leaves. This is not an easy point to settle satisfactorily. It appears that, as recorded above, there is no noticeable scorching of foliage which has been carefully protected ; and indeed we have a good deal of evidence emphasising the impenetrability of the undamaged leaf cuticle of ordinary healthy summer foliage. For example, the general surface of healthy leaves stands immersion in 5 % or even 10 % copper sulphate solution remarkably well ; and on repeating many of the experiments with damaged and undamaged foliage described above, but using 5 % copper sulphate solution in place of the Bordeaux mixture, almost identical results were obtained. The damaged leaves indeed " scorched " worse with copper sulphate than with the Bordeaux mixture, but the undamaged leaves remained almost entirely unaffected, unless the time of contact was very prolonged.

The general conclusion which may be drawn from a large number of experiments on the effects of solution of copper sulphate upon the foliage of different varieties of apple is that, except where the leaves are originally damaged in some way, a short time of contact with a weak solution causes little or no immediate injury, though a longer time of contact may initiate injury to the under surface[2]. Even, however,

[1] Confirmed experimentally by Crandall (*loc. cit.*) and by Hedrick (*New York Agric. Expt. Sta. Bull.* 287).

[2] It is somewhat difficult to understand exactly what is the position taken by Crandall with regard to this point. On p. 232 of his Bulletin, after describing some experiments, he concludes that " the uninjured epidermis of apple leaves was not permeable by copper sulphate solutions": whilst his conclusion No. 16 runs ".... burning quickly follows applications of copper sulphate even when the solutions are very dilute." Possibly the latter statement refers only to damaged foliage, in which case his observations are in full agreement with those here recorded.

after immersion for one hour in a 5 % solution or for half an hour in a 10 % solution the general surface of healthy leaves is not seriously injured. It must be mentioned, however, that with all leaves, damaged or undamaged, treatment with copper sulphate affected the hairs on the under surface, resulting in slight yellowish discolouration, which on close examination were found to be due to the staining of the cell walls. It also hastened the death of late autumn foliage.

By coating one or other of the surfaces of the leaf with vaseline, it was possible to compare their behaviour towards copper sulphate solution, and it was thus found that the upper surface, where quite free from damage, possesses a remarkable power of resistance to the penetration of the solution. Even when the liquid was allowed to dry on the leaves, injury to the upper surface was confined to certain areas, usually evidently arising from some original damage. The under surface is more easily affected: possibly the presence of stomata (in the apple) on the under surface of the leaf only may have some bearing on this point.

These observations apply, however, only to summer foliage. When similar experiments are tried in the late autumn the results are different. The effect of covering autumn leaves, whilst still on the trees, with "no-excess-lime" Bordeaux mixture is to cause considerable and apparently general scorching over most of the leaf surface, accompanied by premature defoliation. When ordinary Bordeaux mixture (containing excess lime) is used, there is more scorching than is noticed in the summer, but the action is not severe. With 5 % copper sulphate solution the leaves very soon shrivel up and drop, and the presence of copper can be traced inside the stem lower down than the parts actually immersed[1]. There is in these cases apparently a general scorching independent of the presence of visible injuries, and of a somewhat different character to that which occurs in the summer. The cuticularised walls of the cells are found to be stained a pale greenish colour, in a manner similar to the leaf-hairs already mentioned.

Possibly under autumnal conditions changes take place in the nature of the cuticle, which lead to the production and absorption of soluble copper over the general surface of the leaf, the Bordeaux mixture thus damaging underlying cells in spite of the really uninjured leaf surface. On the other hand, the possibility of the presence of small injuries was not entirely excluded in these experiments, though the foliage was chosen for its generally sound appearance.

[1] See also p. 18.

The behaviour of apple foliage in the summer condition towards Bordeaux mixture appears to be typical of that of a variety of other hardy plants. The leaves of wallflowers, privet, and violet have been similarly tested and in each case there has been no scorching of uninjured foliage. It is well known, however, that very great variations in susceptibility to scorching are shown by different plants. Some are peculiarly susceptible, and in such cases the general character of the scorching strongly suggests that a change in the nature of the cuticle or, perhaps, the presence of groups of uncuticularised cells rather than local injury is responsible. It is possible that the cuticle in these instances is normally more or less permeable, just as the cuticle of apple leaves appears to become in autumn. Salmon's work[1] on the susceptibility of certain varieties of gooseberries to scorching injury after spraying with lime sulphur washes of various strengths appears to bear out this point; varieties such as Lancashire Lad, Crown Bob, and Berry's Early remaining unaffected by the spray when treated in early summer, while later a wash of the same strength causes scorching. It was also shown that certain kinds such as Valentine's Seedling and Yellow Rough were regularly injured, whilst others such as Whinham's Industry, Rifleman and May Duke escaped damage even when a wash of more concentrated strength was used.

It may be said in conclusion that the evidence seems complete as regards the part played by injuries to the leaves in causing scorching of apple foliage following spraying with Bordeaux mixture; whilst under some conditions it would seem that scorching might also occur over the general surface of the leaf and unconnected with the occurrence of injuries, though this is less certain. No doubt such action if it takes place is more important in foliage such as peach and apricot where either the cuticle as a whole or certain parts of the leaf surface appears to be less resistant than is the case with the apple.

The Penetration of Copper from Bordeaux mixture into the Plant.

The action of the copper of Bordeaux mixture upon plants is not confined to the surface. It is found that under certain conditions plants which have been sprayed absorb some copper either through their foliage or their roots.

Millardet and Gayon (*Journ. d'Agric. Prat.* 1887, p. 125) were the first to refer to the absorption of copper by leaves. They proved the

[1] *Journ. Bd. Agric.* XVII, p. 881; XX, p. 1057.

presence of copper in the cuticle of grape leaves which had been treated with various strengths of copper sulphate solution: no information is however given as to the condition of the leaves as regards injury. Rumm (*Ber. Deut. Bot. Ges.* XI, p. 79) and later Crandall (*loc. cit.*) found no penetration of copper from copper sulphate solutions through the cuticle of uninjured apple leaves. Pickering on the other hand (*loc. cit.* p. 113) showed the presence of copper in the ash of "perfectly sound" apple leaves treated with various copper solutions.

During the present investigation *damaged* apple foliage which has been sprayed and which shows any signs of scorching has always been found to contain some copper. Repeatedly, such leaves have been examined. The procedure adopted has been first to wash the sprayed surface in dilute acid, great care being taken to wet every portion with a brush, then to transfer the leaves to running water for half an hour or longer, after which they are dried and ignited and the ash tested for copper. In the case of scorched leaves, copper is invariably found to be present in the ash. On the other hand, with really uninjured summer apple foliage, copper has not been detected in the ash[1]. Probably the presence or absence of slight injuries is sufficient to account for the conflicting results of other workers.

A comparison of the results of dipping healthy summer and autumn apple foliage into 5 per cent. $CuSO_4$ is very striking. As has been mentioned, the summer leaves are little affected by this treatment; the autumn leaves, however, besides being severely scorched, absorb a good deal of copper which is passed down into the stem, killing all the interior cells for some distance below the portion actually immersed. Crandall has recorded a similar translocation of copper through the stem of apple trees into which solutions of copper sulphate had been injected through wounds. Browning of the leaves was also observed.

It would appear that there is no absorption of copper through the normal cuticle of a healthy apple leaf. Autumnal changes, however, as already shown, lead to a partial change in the nature of the leaf surface, and there is a varying amount of action of Bordeaux mixture resulting in injury and absorption of copper.

Turning now to the behaviour of *potato* foliage towards Bordeaux mixtures, we find rather a different state of affairs. The cuticle appears to be distinctly more permeable than that of normal apple leaves. On covering potato leaves either with the ordinary or the "no-excess-lime" mixture there is certainly some absorption of copper, for it can readily

[1] By the ferrocyanide test.

be detected in the ash of treated leaves, but on the other hand there is seldom any noticeable injury to the cuticle.

The cuticle of potato leaves is of quite a different type to that of apple leaves and either all the cells or some only (possibly the hairs) are evidently capable of exerting a slight solvent action upon the copper compounds, which gives rise to a limited absorption insufficient to cause injury to the cells. Copper absorbed in such a manner as this appears to be rapidly translocated and dispersed without harm to the living cells through which it passes. Possibly the removal is sufficiently rapid to prevent the toxic dose being reached at any one point.

Another series of experiments showed that copper can be absorbed by potatoes through their *roots*. A number of potato plants were grown in pots in soil mixed with considerable quantities of various Bordeaux mixtures, so that the tubers were actually in contact with the copper containing compounds. Samples of foliage were taken from each plant, dried, ashed, and the ash tested for the presence of copper.

The following are the notes obtained from this series on testing the foliage on two occasions separated by about a month:

Soil treated with	Copper reaction I	Copper reaction II
"No-excess-lime" mixture	Faint, but distinct	Strong
Cooper's Bordeaux powder	Very faint	Very faint
Ordinary Bordeaux mixture	Very faint—uncertain	Faint, but distinct
Control	Nil	Nil

Here again we have apparently an absorption and translocation of copper through the plant from the roots to the aerial parts without injury to cells during transmission. There is in this case some local injury to the surface of the root.

Precisely the same thing was found to occur with broad beans when these were grown with their roots in contact with the basic copper sulphate; an appreciable amount of copper was found to be present in the leaves. Analysis of the foliage of control plants showed absence of copper. The influence of the absorbed copper was not, so far as could be observed, injurious, the amount of growth often being equal to that of the control plants, and where appreciably less, probably this was attributable to the disorganisation of the root system.

What the physiological effect of the absorbed copper may be is at present uncertain. In a set of practical spraying experiments it was noticed that in all cases (as has often been recorded) the colour of the sprayed plants differed from that of the unsprayed, being of a darker and rather bluish-green shade. This was especially noticeable in plants treated with Burgundy (Soda-Bordeaux) mixture. A further point was that the darker green colour was not confined to leaves coated with the spray. New foliage which developed after the spraying, showed the colour effect almost equally well. A comparison of sections of leaves of treated and untreated plants showed that the colour change was due mainly, if not entirely, to the difference in the nature or amount of the chlorophyll in the mesophyll tissues. It was not possible to decide positively, whether there was also a difference in the colour of the cuticular epidermal walls and of the hairs.

A colour effect was also noticed in the case of the broad beans. The foliage of the copper-containing plants was on the whole noticeably darker in colour, although considerable variation in this respect, due partly at any rate to the conditions of the experiment, was met with. In marked cases the tint of the green colour differed considerably from that of the normal leaf green of a healthy bean plant, being of a distinctly bluer or greyer character. Comparison of alcoholic extracts of chlorophyll from copper-containing and copper-free foliage by spectroscopic examination and other methods failed to reveal any difference between the two; and the colour of the extracts, unlike that of the leaves themselves, was practically identical. In making the chlorophyll extract, however, it was noticed that in the case of the copper-containing foliage there was considerable difficulty in obtaining complete extraction of the colouring matter; and generally after extraction the tissues instead of being quite colourless, contained areas of a pale purplish-black tint. Sections of the tissues showed that this colour was due not so much to colouring matter within the cells as to cell walls stained with this tint.

The question of the influence of the copper in potato and other foliage on the power of resistance of the plant to fungoid attack is still under investigation.

The results of these observations on foliage injury and the absorption of copper by the plant from Bordeaux mixtures may be summarised as follows:

(1) Cells with readily permeable walls (such as germ tubes of fungus spores, root hairs, the interior tissues of leaves, etc.) exert a considerable

solvent action on the particles of the copper compounds with which they may come into contact. There is rapid absorption of the dissolved copper followed by death of the cells. In the case of injured foliage such action results in scorching.

(2) The amount of inter-action, if any, between other types of cells and the copper compounds is determined by the nature of the cell wall. Direct absorption of copper by leaves of certain types takes place with or without local injury, depending on the nature of the leaf surface. Translocation of the absorbed copper to other parts of the plant may follow.

(3) Copper may be absorbed through the roots of certain plants (potatoes, beans), with local injury to the root. This absorbed copper can be translocated to the aerial parts of the plants without injury to the cells through which it passes.

NOTES ON THE GREEN SPRUCE APHIS (*APHIS ABIETINA* WALKER).

By FRED. V. THEOBALD, M.A., etc.

During 1913 a very severe attack of the aphis described by Walker in 1849 as *Aphis abietina* took place on spruce trees of various kinds. This aphis I have found in considerable numbers in the south of England for many years, but I have never known it until the summer of 1913 to do any serious harm.

Since Walker's original account given in the *Annals and Magazine of Natural History*[1], the only references I know of it are those given by Buckton in his *Monograph of British Aphides*[2] in 1877 and in Gillander's *Forest Entomology* in 1908[3]. I have also recorded it from Worksop[4] in 1910 and from Kent in 1911[5]. P. Van der Goot[6] places this in his new genus *Myzaphis.* I have known however of this insect since 1889 when it was abundant on the Norway spruce at Kingston-on-Thames, and on some of the spruce trees in Richmond Park.

I can find no reference to this spruce aphis on the Continent, but I remember finding it near Odde in Norway in 1891.

Like most aphides it is of erratic appearance. Districts in which it is quite common one year, may suddenly become comparatively free from it. Then after a lapse of time it may occur again in quantity. The only years in which actual damage has been noticed however are 1846 and 1913.

It is quite possible that the damage caused by it on other occasions may have been put down to other causes, such as unsuitable soil, drought, etc.

[1] *Ann. Mag. Nat. Hist.* III, Ser. 2, pp. 301–302.
[2] *Mono. Brit. Aph.* II, p. 43, pl. xlix, figs. 3 and 4.
[3] *Forest Entomology*, p. 304.
[4] *Rept. Eco. Zool.* for year ending Sep. 1911, p. 132.
[5] *The Entomologist*, XLIV, p. 398 (1911).
[6] *Tijdschrift v. Ent.* LVI, p. 96 (1913).

There is no doubt it is influenced very largely by the weather. Its destructive nature under certain weather conditions can be understood by the notes given here and the photos showing the damage, and it may here be pointed out that both in the 1846 and 1913 attacks, that the previous winters were noted for their mildness and dampness. No doubt these conditions place the Piceas in an unhealthy condition, and that in consequence the effect of these sucking insects becomes much more marked and at the same time the mild weather enables the aphis to flourish right through the cold months.

Description of the Insect.

Apterous viviparous female.

Green, oval, convex, with a darker line on each side of the body.

Fig. 1.
Aphis abietina Walker. A Alate female B and C Apterous viviparous females.

Head yellowish-green to fawn colour, with two foveae; a small prominence on each side of the head at the base of the antennae.

Antennae about half the length of the body, pale yellowish-green, darker at the tips, the first segment very wide, second small and narrow, third longer than the fourth, the fourth a little longer than the fifth, the sixth about as long as four and five, the basal area as long as the flagellum, which is blunt; all the segments markedly imbricated.

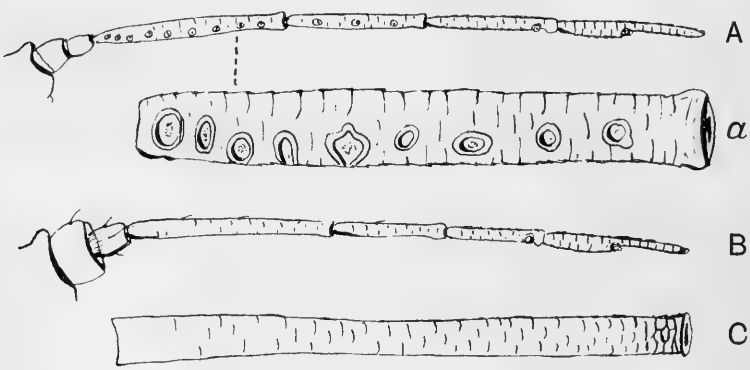

Fig. 2.

Aphis abietina Walker. *A*. Antenna of alate female *a*. further enlarged third segment. *B*. Antenna of apterous female. *C*. Cornicle of alate female.

Eyes dull red. Proboscis green, dusky at the apex, reaching to the third coxae.

Cornicles pale yellowish-green, some with a brownish tinge, apex in some dusky, about one-fourth the length of the body, a few lines and large reticulations at the apex, remainder strongly imbricated. Legs green, tarsi, tips of femora and the tibiae dusky. Cauda green, rather long.

Length, 1 to 1·5 mm.

Winged viviparous female.

Green. Head large, a pale olive green to pale fawn colour; antennae nearly as long as the body, pale brown, the third segment with 9–12 large sensoria along its whole length, the fourth shorter than the third, with 2–4 sensoria; the fifth slightly shorter than the fourth, with a sub-apical sensorium, the sixth not as long as four and five together, the basal area only a little shorter than the flagellum; all the segments markedly imbricated. Head with two prominent but small

frontal processes at the base of the antennae. Eyes deep red; stemmata prominent.

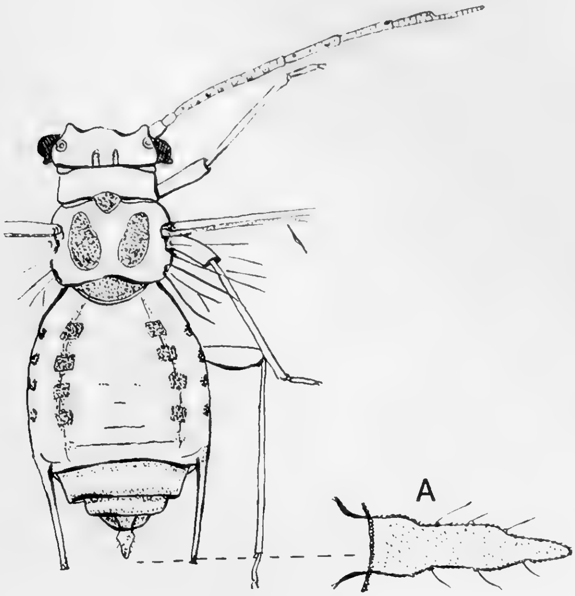

Fig. 3.
Aphis abietina Walker. Alate viviparous female and further enlarged cauda A.

Pronotum fawn coloured to green; mesonotum greenish with darker lobes, scutum and scutellum in some brown; venter of thorax dark.

Abdomen bright green with dark sub-median lines, really made up of four darker spots, also traces of four pairs of darker lateral spots; segments caudad to the cornicles marked and somewhat darker than the rest. Cauda pale green, pointed, moderately long.

Cornicles long, thin, straight, cylindrical, reaching beyond the cauda, pale greenish to greenish-brown; in some slightly darkened at the tips; apex with a few transverse lines and large hexagonal areas, not strongly imbricated.

Legs pale green in some, pale brown in others, rather short; femora thick; tarsi and apices of the tibiae slightly darkened. The wings are large, much longer than the body with rounded apices; the stigma and veins pale brownish-green to grey, subject to considerable variation in veination; the veination in the two wings often being totally unlike one another (*vide* Figs. 1 A and 4).

Proboscis green, dusky at the apex, reaching to the third pair of legs. Cauda with three long chaetae on each side.

Length, 1 to 1·8 mm. *Wing expanse*, 5 to 5·2 mm.

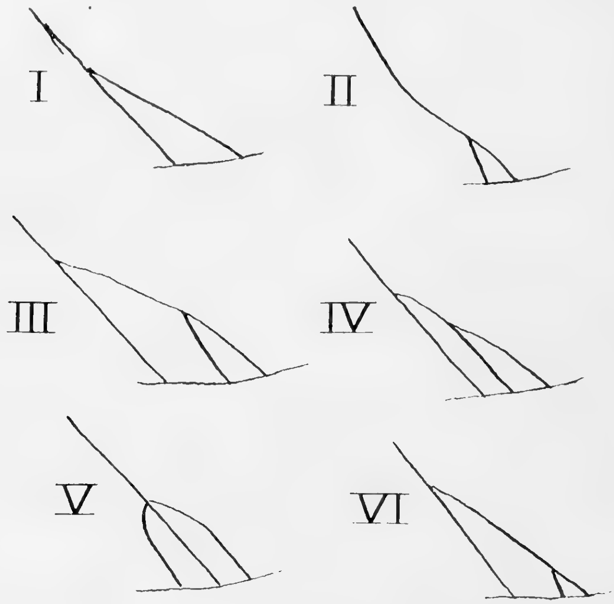

Fig. 4.
Variations in veination in *Aphis abietina* Walker.

Localities where found.

England. Alnwick, Northumberland (Gillanders); Great Lalkeld, Penrith, Cumberland (Britten); Thirlmere, Grasmere, Manchester Corporation Water Works, Westmoreland (Edwards), Windermere (Aymer Roberts); near Flamborough Head, Yorks. (Theobald); Holmes Chapel, Cheshire (Young); Great Staughton, near St Neots, Huntingdonshire; Little Hadham, Herts; Widdington, Essex; Kew Gardens, Surrey; Rudgwick, Sussex; Woking, Guildford, Worplesdon, Esher, Kingston in Surrey; Panton, near Wragby, Lincs.; Wye and Goudhurst, Kent; Tiverton, Devon; Fowey, Cornwall; Worksop (Theobald); Culford, Bury St Edmunds, Suffolk (Henry).

Wales. Aberglaslyn and Criccieth, Merionethshire[1] (Theobald).

[1] This aphis swarmed in Aberglaslyn in 1906. The attacked trees have since been cut down.

Ireland. Rathdrum, Co. Wicklow; Dundrum, Co. Tipperary; Kilrush, Co. Clare; Camolin, Co. Wexford.

I have been unable to obtain any records from Scotland.

Food plants.

There is no doubt that the genus *Picea* is the normal food plant of this aphis, but I have taken it in numbers on Scots firs on six occasions and once on a Weymouth pine at Wye.

Its normal food plant is probably *Picea excelsa*, and until recently I have not seen it on any other species of conifer except the Scots and Weymouth pine[1].

The species of *Picea* on which it has been recently found are the following:

Picea excelsa, P. sitchensis, P. pungens, P. engelmannii, P. nigra, P. alba, P. gigantea, P. rubra, P. morinda, P. orientalis, P. monstrosa, P. omorica, P. kosteriana, P. glehire.

Apparently immune varieties.

Certain varieties are apparently immune, such as *P. polita, P. hondoensis, P. alcoguiana* and *P. alaskiana* and in some places *P. omorica* has not been attacked.

Varied degrees of attack on different species.

Speaking generally, the Sitka spruce is by far the most damaged, but this does not apply everywhere. For instance in the small nursery belonging to Wye College I was unable in 1913 to find a single specimen of this insect on the Sitkas, but *Picea excelsa* close to them were found to have any number on them and a few were badly damaged.

At Kew *P. sitchensis, P. pungens* and *P. engelmannii* were badly damaged, even trees 20 to 30 feet high, *P. nigra* and *P. alba* were in some cases damaged, others escaped. It was noticed here that the European and Asiatic species were damaged much less, the only seriously injured one being *P. excelsa.*

In a large nursery I visited at Woking I found it doing great damage to *P. pungens, P. alba* and *P. sitchensis* and a great deal on *P. excelsa.*

In my garden one large *P. excelsa* was entirely browned by it and I think is dead, another was partly ruined, whilst *P. pungens* var. *kosteri,*

[1] I may point out here that Dr Henry in the *Gardeners' Chronicle* says the aphis has not been noticed on any genus except *Picea.*

a large needled, very glaucous form (Fig. 7) had some amount of aphis on three specimens, but two were affected scarcely at all and the aphis increased very slowly, the third however, which had been previously damaged by accident, was badly infested with this insect. All the other

Fig. 5.
Sitka Spruce attacked by *Aphis abietina* Walker. Early stage showing needles turning brown and falling.

English records I have are on *P. excelsa*. Writing from Dundrum, Co. Tipperary, Mr A. McRae says, "I find the common spruce of all ages, from nursery stock to matured trees of 80 years or over, are badly infested. On matured spruce the effects are most marked on partially

isolated trees, growing on road sides or along the margins of belts and woods, on comparatively low ground, say 300 to 400 feet altitude. I also find the aphis in comparatively large numbers on old trees of white American spruce, but up to the present they do not show any very serious results. At Dundrum the Sitka would appear to succumb most

Fig. 6.
Picea excelsa showing denudation on upper portion of shoot after a year's attack.

readily to the attack ; in the nursery, however, the Sitka are not affected to the same extent as the spruce, but the latter are larger trees and have been longer in stock than the Sitka."

Writing from Avondale, Rathdrum, Co. Wicklow, Mr J. Black sent the following list of species attacked :

P. sitchensis, badly attacked, six years planted, 8—10 feet high.

P. excelsa, attacked to some extent.

P. morinda, two years planted, partially defoliated.
P. rubra, *P. alba*, six years planted, attacked similar to *excelsa*.
P. pungens, four years planted, attacked quite as badly as *sitchensis*.

Fig. 7.

Picea pungens v. *kosteri* showing aphides but little damaged.

Single specimens attacked are as follows:
P. orientalis, slightly affected.
P. engelmannii, badly attacked.
P. kosteriana, badly attacked.
P. glehire, badly affected.

P. monstrosa, badly affected.
The only species not affected here are:
P. polita, *P. omorica*, *P. alcoquiana* and *P. alaskiana*.

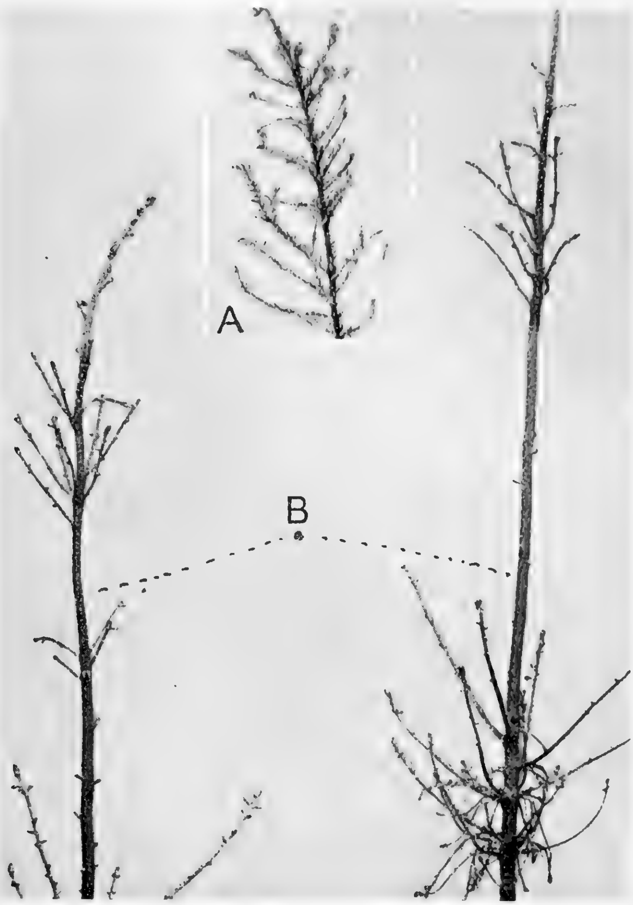

Fig. 8.

B. Sitka Spruce completely defoliated by *Aphis abietina* Walker. A. First stage of attack.

Different effects produced on different varieties.

Two very marked different effects are produced by this aphis. In *P. sitchensis* the damaged needles soon fall and complete defoliation results, as shown in the photos reproduced here. In *P. excelsa* the

needles turn brown, but the majority hang on and the tree looks as if it had been scorched by fire. In one tree in my garden the leaves have partially kept on into the spring of 1914. The damaged needles certainly fall, but nothing like to the same extent as in the Sitka spruce.

In *P. morinda* they become partly defoliated; in *P. engelmannii*

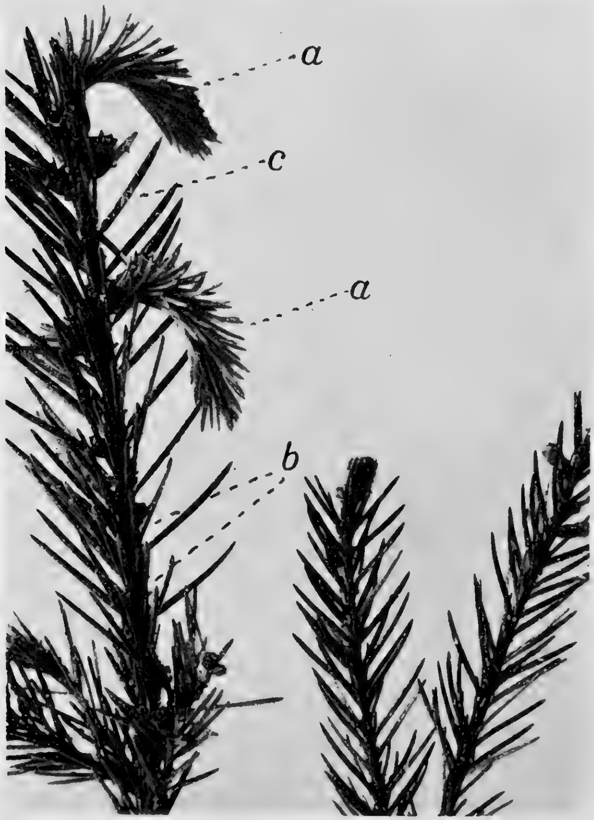

Fig. 9.

Picea excelsa showing a few fallen needles and young growth unattacked. *a.* young growth. *b.* some nodes where needles have fallen. *c.* discolouring of needle.

the trees do not become defoliated, nor in *kosteriana* ; one of the latter attacked in my garden has every browned needle still holding on, much more so than in *excelsa.* Partial defoliation takes place according to Mr Black in *glehire* and *monstrosa.*

Young *excelsa* do not present the same appearance as old ones when attacked, the needles instead of turning brown are mottled, where the aphis sucks yellow spots appear and this lasts through the winter. Writing from the Camolin Forestry Centre, Co. Wexford, Mr A. Stewart says "the aphis is extremely plentiful on young Sitka and Norway spruce, but that in May not much damage had been done to the latter, but the Sitkas are in many cases practically defoliated."

Fig. 10

Sitka Spruce defoliated by *Aphis abietina* at Arndale (Dr Henry).

Mr Murphy of the Kilrush Forestry Centre, Co. Clare, found the few thousand Sitka spruce attacked, but not badly, but that both Sitkas and Norway spruce in the plantations were practically immune.

It thus seems that both the Norway and Sitka spruce are badly attacked and then next comes *pungens*, but that there is a marked

difference in the appearances produced, *i.e.* complete and rapid defoliation in the Sitka, browning and slow defoliation in *excelsa* and still less defoliation in *pungens* and scarcely any in the glaucous variety *kosteriana.*

Life-history.

So far I have been unable to find any sexuparae and I have searched carefully for four years.

I have found apterae from early January on to December. The first alatae occurred on the 20th of March at Woking, but in small numbers. At Wye I have never noticed any until June and in July many occurred and went on appearing in numbers into August. After August the trees kept under observation showed comparatively few aphis until the end of September, when they again became fairly common and some could always be found right into December. These winter apterae seldom producing any living young. At this time both mature and immature apterous viviparous females occur.

Gillanders says that it may be found in winter. Mr McRae writes me that where infestation is serious the aphis appears to live on the trees throughout the winter, and Mr Black also noticed that this aphis persists throughout the year. I have vainly searched for sexuparae this year, a year when the sexual brood of aphides has been particularly noticeable.

The apterous aphides usually occur along the needles, a single one settling on each needle and giving rise to a colony of young, which later spread out and do the same; where the apterous mother feeds a yellow spot occurs, sometimes with a reddish tinge and which later darkens; two or three of these spots on old trees seem sufficient to kill the needle, whilst in young ones they remain, the needles but seldom completely dying. The aphides also wander about on the shoots and remain and feed there.

They do not seem to attack the new growth to any extent in summer, but in autumn and winter a few may be found on the young growths.

In October and November I counted about six apterae to every foot of branch examined and a few small young with them. The insect is very sluggish both when in the apterous and alate stages, but if a branch is cut off they become active in a few hours and wander away from the needles.

It thus appears that this insect lives normally through the winter as apterae and that sexuparae must be very rare and are so far unknown.

This winter, 1913–1914, I found apterous viviparous females again right through the winter, a weekly search being made, and they now and then produced living young.

Natural enemies.

In spite of this aphis having a very large number of natural enemies, they do not seem to have any effect upon it when weather conditions are favourable to it and unfavourable to the host plants. I have failed to find any parasites or predacious insects attacking it in winter when they might clear off the comparatively small numbers that then occur, nor do they appear until June or July, long after the aphides have done their worst harm.

Later in the year they are preyed upon by a number of natural enemies. The chief amongst these are several spiders, at least two species of Phalangidae or harvest men, and the adults of *Scymnus* sp. and its larvae to a small extent. That spiders and phalangids do enormous good there is no doubt at this time. But the most interesting enemy this aphis has that I have seen is the long eared bat. A tall tree in my garden was every night in July surrounded by these animals, hovering like a large moth at the tips and sides of the top branches, and clinging on to them. Wishing to know what they were so assiduously hunting for, I shot one and found it was full of hundreds of *Aphis abietina*, not only the alate females, but the apterae and nymphae that they must have taken from the needles.

I bred only two Chalcids. Several Syrphid larvae were active amongst them and *Adalia bipunctata*.

Treatment.

In plantations of course nothing can be done that would pay to do, but in nurseries and where any special trees we wish to save are attacked we can very easily destroy this pest. Paraffin jelly, nicotine and soft soap, quassia and soft soap, soft soap alone, lime sulphur wash and such patent washes as White's Abol, MacDougall's Summer Wash, and Cook's Tobacco Wash were tried. All with the exception of lime sulphur and soft soap alone killed great numbers, but the best results were obtained with Cook's Tobacco Wash, then with nicotine and soap and slightly below these came White's Abol, MacDougall's Summer Wash and paraffin jelly, then soft soap and quassia. Soft soap alone was not

found sufficiently penetrating to do much good. Lime sulphur at summer strength had no effect at all. The main thing is to give a very fine spray applied with force and to well wet the foliage. Winter treatment with strong paraffin jelly yielded excellent results and probably will prove to be the best method of treatment.

I have to thank Dr Henry for the information sent me from Ireland.

POLLINATION IN ORCHARDS.

By F. J. CHITTENDEN, F.L.S.

I am venturing to bring the question of pollination in orchards before this Association, because, in the first place, it is one of extreme economic importance in the fruit-growing industry, since it touches one of the fundamental points for consideration in planning the planting of an orchard ; and, in the second place, the problems its phenomena raise include many of deep biological importance. Like so many of the questions the practical man has at present to solve by empirical methods, and which await scientific investigation, it touches more than one side of biological science.

Historical note. Swayne was the first, in 1823, to demonstrate by experiment that certain varieties of pears were self-sterile, *i.e.* required the intervention of pollen from another variety in order to cause fruit production. Peaches, old gardening literature shows, were thought to require pollen of other varieties, but experimental evidence seems lacking in regard to this fruit. The matter, although set out very clearly by Swayne, was apparently lost sight of until about 1890, when Waite re-discovered it for pears in America, and later found the same thing was true of apples. Considerable attention has been, and is being, devoted to the problem with these and other fruits in America, and to a less extent in Australia and other of our great fruit-producing colonies.

Our own experiments, begun at Chelmsford in 1902, confirmed Waite's observations, and clearly established the fact that a large proportion of our commonly grown varieties of apples and pears failed to set fruit unless pollen from some other variety was placed upon the ripe stigma. More recently Backhouse, and, later, Sherrard, has shown that our varieties of plums fall into two more or less distinct groups of self-sterile and self-fertile types. Cherries, peaches, nectarines, and probably grapes also, apparently show the same phenomena. Hooper's experiments at Wye are confirmatory. Some work has also been done by continental biologists upon the problem, but especially by Ewert in

Germany, and Müller Thirgau at Zurich, who have written several papers on " Parthenocarpie "—an expressive term which we owe to France.

Meaning of Terms " Self-sterile " and " Self-fertile." The terms " self-sterile " and " self-fertile " have been somewhat loosely applied in connection with this subject. In the strictest sense, self-sterility would mean that, although normal ovules were produced, without the intervention of pollen from another variety of the same kind, they would stop development at the egg-cell stage, and no *seeds* would be produced; conversely, in self-fertile varieties, the pollen from the same flower, or from a neighbouring flower on the same tree, would fertilize the egg-cell, and seeds would be produced.

We have purposely said " another variety," not " another plant," because the different trees of, say, " Cox's Orange Pippin " apple are all parts of the original tree which was raised at Colne in Middlesex, just as all the trees of " William's Bon Chretien " pear in all parts of the world (it is called " Bartlett " in America) are all parts of one, propagated by vegetative methods. The different trees of one variety are, although they have a certain individuality of their own, not individuals in the same sense as plants raised directly from seeds would usually be. The varieties of fruit trees are comparable with separately raised seedlings. All the trees of the apple " Blenheim Orange " are, for our purpose, but parts of one individual, all those of " King of the Pippins " of another, all those of " Ribston Pippin " of another, and so on.

This is the usual meaning of self-sterility in animals and in other plants, but with the fruit-grower the term has another significance. The important point for him is whether or not the fleshy envelope of the seed is matured—the seed itself concerns him not at all, and we find that a considerable number of varieties of apple and pear produce perfect fruits, except that they are seedless, when pollen of other varieties has no access to the stigmas. I have used the term " self-fruitful " for the production of fruit without the intervention of foreign pollen, whether seed is produced or not. Seedless apples and pears are by no means uncommon. They may be found any year, in any orchard, produced from summer flowers. They are common in such varieties as " Lord Derby " and " Golden Spire," when these varieties are not open to pollination by other varieties, for these are self-fruitful, though not self-fertile. They are normal in the pear " Ruyshe's Coreless " and in the apple " No-pip."

It is this form of fruit which is called parthenocarpic, but it is not yet clear whether pollination of any sort is necessary for the production of these seedless fruits. In cucumbers it certainly is not, for commercially grown cucumbers reach a large size without fertilization of any kind, and contain no fertile seeds. The histories of many seedless fruits, like the banana, and of the well-known seedless oranges, and other seedless fruits, seem never to have been thoroughly worked out, though something has been done with seedless grapes by Müller Thirgau. There may well be two types of parthenocarpy.

Further, it is not yet clear whether, in the case of the relatively few apples and pears which produce seed without the intervention of foreign pollen, the seed is produced parthenogenetically or not.

Parthenocarpic fruits are almost unknown in the plum and cherry.

Cause of Self-sterility. It is in only the rarest cases that apples or pears have unisexual flowers. Both ovules and pollen in some two hundred varieties of apples, and in the same number of pears, which we have examined, are apparently properly developed. The pollen is capable of germination in every variety, though the per cent. of germination varies greatly in different seasons. So far as our experiments have gone, it seems that the pollen of any variety of apple is capable of fertilizing the egg-cells of any other variety of apples, and similarly with pears. (Backhouse has shown this is not the case in plums and cherries.) Naturally, the enormous number of possible combinations has not yet been exhausted. The point needs further investigation, especially from the economic point of view, for some variety may be better fitted to induce fruit production in some other than are other varieties. There is sufficient evidence, however, to show that, while the pollen of one variety may be quite impotent when applied to the stigmas of flowers of the same variety, yet it is capable of fertilizing another variety and of inducing the production of viable seed. Extended microscopic examination of the apple flower has failed, so far, to reveal to us, either in its structure or in its development, anything to account for this remarkable state of things, both pollen and ovule appear normal in every way. We have been repaid in the rather time-consuming operations this examination has entailed by the discovery of one or two curious and possibly significant facts hitherto unrecorded, but these facts have no bearing upon the present question. We have, here, a very curious phenomenon, rather wide-spread in the vegetable kingdom, of incompatibility between the gametes of a hermaphrodite flower. Does such incompatibility exist among hermaphrodite animals? and

what can be its explanation? A hypothesis which would fit all the facts has, so far, evaded us, nor have we been able to form a mental picture of what self-sterility means, and the whole question seems wrapped up with another of the deepest biological significance, viz. what is the real meaning of individuality?

There is some evidence that this self-sterility is not absolute in, at least, some varieties. That is, a variety self-sterile here, may be self-fruitful somewhere in the range of its distribution, or in some seasons. It seems almost that, where the variety " does " best, it is more likely to be self-fruitful (whether self-sterile or not, the recorded observations do not make clear, though our own experiments tend to show that, *e.g.* in " Cox's Orange Pippin," in which self-sterility is the rule, when exceptions occur, seed is produced). This fact no doubt explains the contradictory evidence afforded by different observers on such a pear as " William's Bon Chretien," which produces fruit without foreign pollen in some places, not in others.

There is the further question as to whether vegetative vigour may not be a factor in the production of the seedless fruits already alluded to. It may be so, for we find vigorous trees of the pears " Conference " and " Durondeau " almost invariably very fruitful, and, where protected from foreign pollen, bearing seedless fruits, while, among apples, " Stirling Castle " very rarely fails.

It seems quite possible that the pollen of a self-fruitful variety such as these may have the function of stimulating the development of what may be called the vegetative part of the fruit, though it fails to effect fertilization. This is a very commonly observed phenomenon in the case of many orchids, even foreign bodies falling upon the stigma causing the production of fruits (of course, usually seedless). An interesting instance of the effect of stimulation of a rather novel character came to my notice not long since, and it was not an isolated instance. All the pears on a tree, except those attacked by the pear midge *Diplosis pyrivora*, fell very early, failing to swell, apparently owing to defective fertilization. Those attacked remained till the end of May, and, as is their wont, swelled very considerably. I commend this observation to the notice of our entomological members. The case of the absolute effect of the stimulus of egg-laying, or of the larval presence, is not quite conclusive, but it is certainly suggestive.

Some Economic Aspects of the Question. It is clear that a knowledge of varieties dependably self-fruitful would at once show what varieties might be planted in large blocks without fear of failure from this cause,

and this is an economical method of planting an orchard, since the same operations can be carried out simultaneously over a considerable and consecutive area. On the other hand, with self-sterile varieties, the knowledge of what varieties to interplant is important. It is quite certain that, until we have much more light on the causes of self-sterility, it will not be possible to give the authoritative advice for which the grower is entitled to look.

We are experimenting in the gardens of the Royal Horticultural Society, with the object of ascertaining what varieties of apple and pear are fertile *inter se*, and are carrying out other lines of work on the matter, and have just put up a large orchard house for extending our work, but, as we have indicated, observations in other localities upon particular points are of the utmost importance, in order that some of the questions at issue may be solved. The wish to bring this very important matter before the notice of those who may have the opportunity of carrying out some work upon it, is one of my objects in writing this note.

Certain points are, of course, clear, and the plainest is that varieties flowering at approximately the same time should be planted together. We have given, in the Journal of the Royal Horticultural Society, lists of varieties of apples and pears, in their relative orders of flowering, with the object of guiding the planter on this particular point, and we have there compared our own average dates of flowering with those of the same varieties in other parts of the world. These comparisons make it clear that approximately the same order of flowering is maintained by the different varieties all over the world, no matter what the climate may be, so that a list founded, upon the average for several years, drawn up in one locality, will prove a reliable guide in any other fruit-growing district.

Another point of economic importance lies in the relative size of fruits produced by the aid of foreign pollen and without it. They are, as a rule, larger when seeds are produced, and are reputed to be sweeter.

The Carrying of the Pollen. There remains another point of general interest : How is the pollen carried ? The suspension of glass slips smeared with glycerine a few feet on the leeward side of blossoming apples and pears, has resulted in the capture of a very small amount of pollen, in marked contrast to the amount of pine pollen which we have so collected from pine trees as much as a quarter of a mile distant.

A large number of rather desultory observations have been published regarding the insects which effect inter-pollination in the apple and pear, and it is certain that insects are the chief agents. But some have claimed

for the hive bee a great preponderance of visits over those of other insects, and it would be a good thing to get the matter cleared up.

The record of captures at the flowers is of relatively little value, for that takes no note of the number of visits an individual insect may pay. I have watched a bumble bee, *Bombus terrestris*, for instance, pay 48 visits to different flowers (not all on one tree) in the course of ten minutes. Note ought also to be taken of the length of time over which the visits may extend. The bumble bee is out earlier by far than is the hive bee, and it goes to rest much later, but is the pollen in a fit state to be carried during all these hours ? The fishy scent of the pear, rather like that of hawthorn, no doubt attracts numbers of Diptera, and midges seem particularly partial to them.

Some one recently, too, pointed out the great importance of the hairy wild bees in effecting cross pollination in orchards, and, I am sure, it would be a productive piece of work if the investigation were taken up seriously. The Isle of Wight Bee Disease has practically exterminated the hive bee in many districts, and the cultivation of the ground in and round orchards has destroyed the nesting places of not a few of the insects that, in all probability, effected cross pollination in the past.

A CONTRIBUTION TO A KNOWLEDGE OF THE BELLADONNA LEAF-MINER, *PEGOMYIA HYOSCYAMI*, PANZ., ITS LIFE-HISTORY AND BIOLOGY[1].

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CONTENTS.

[1] Communicated by A. D. Imms, M.A., D.Sc.

1. *Introduction.*

The first record that we have of *Pegomyia hyoscyami* Panz. dates back over a century when Panzer described it in 1809 from Central Europe, including it in the genus *Musca*. Previous to this however Réaumur in the year 1737 gave an admirable account of the behaviour of the larva, with a few structural details, which he found mining the leaves of henbane, *Hyoscyamus niger*. He figured the larva, and drew attention to the resemblance that exists between it and the larva which he found mining in the leaves of the beet. No mention is made of the adult insect, a fact which Vallot noted in 1849, in dealing with the "Pegomyie de la jusquiame." This latter also observes that Réaumur's expectation that the larvae which mine the leaves of the pear would be identical with those found in the leaves of henbane failed in its realisation, for he showed that the adult insects belong to two different genera of Diptera.

This fly has been treated of by various authors and much confusion exists in the literature on the species, due to the fact that it has a fairly large number of food plants. This has led many authors astray, so that it has been described several times under various names, and in one or two cases the same author has described it under two different specific names. There does indeed seem to exist a distinct variety, namely that which attacks beet and mangolds, described first by Curtis in 1847. Much damage is done periodically to these crops both in this country and in Europe as well as in America. In fact so much so is this the case that it often constitutes itself a serious menace to their successful cultivation. In England and in Ireland Curtis and Ormerod recorded damage from various parts of the country, and Carpenter more recently has notified its ravages from Ireland, as also Farsky on the continent and Chittenden in America.

It was with the idea of verifying some points in the life-history of the species and also of unravelling the tangled skein of the nomenclature that I took the opportunity presented to me of rearing the species on *Atropa belladonna*, the Deadly Nightshade, which I believe to be the first record of its being bred from this plant. By means of facilities offered at Holmes Chapel Agricultural College Farm, I was enabled to compare it with the var. *betae* which was obtained from the mangold crop there, and I am also indebted to Professor Carpenter of the Royal College of Science for Ireland for several specimens kindly given to me. In addition I took the opportunity of making a comparison of the larval

characters of *P. hyoscyami* with those of *Pegomyia bicolor* Wied. and of *Pegomyia nigritarsis* Zett. The results of this comparison have been incorporated in this paper. The research was carried out in the Laboratories of the Department of Agricultural Entomology, Victoria University, and in the Experimental Laboratory, Fallowfield. It affords me great pleasure to express my gratitude to Professor S. J. Hickson for the various facilities readily granted to me, to Dr A. D. Imms for many useful suggestions made when the work was approaching completion and to Mr J. T. Wadsworth, who photographed the specimens for text-figures 2, 3 and 4.

2. *Synonymy of the Species and Nomenclature of the Genus.*

The *Katalog der Paläarktischen Dipteren* gives the following list of names which at one time or another were supposed to apply to valid species, and are included therein as synonyms of *P. hyoscyami.*

P. hyoscyami Panz., *P. atriplicis* Gour., *P. chenopodii* Rond., *P. conformis* Fall., *P. cunicularis* Rond., *P. effodiens* Rond., *P. egens* Meig., *P. exilis* Meig., *P. Gouraldi* R.-D., *P. haemorrhoa* Pand.

Var. *Pegomyia betae* Curt., *P. dissimilipes* Zett., *P. femoralis* Brischke, *P. spinacia* Holmgr.

In America, Lintner, in 1881, described the species under the name of *Pegomyia vicina.*

The generic name has not remained constant and the species has been included by various authors at various times in the genera *Musca* (Panzer, Fallen), *Anthomyia* (Meigen, Schiner, Rondani), *Anthomyza* (Zetterstedt), and *Chortophila* (Rondani). According to Stein (1905), Robineau-Desvoidy in his paper on the Myodaires (1830, 595) established the tribe Pegomyidae for a number of Muscidae which are distinguished from the Anthomyiidae by the more or less red colouration of the body, by the small squamae and because in the larval stage they subsist on the parenchyma of leaves. Rondani did not assume the genus *Pegomyia*, but from a consideration of the size of their squamae he disposed of the species in the genera *Anthomyia* and *Chortophila.* Meade in 1883 re-adopted the name *Pegomyia* including under it all Anthomyiids with naked, or at least pubescent antennary bristle, with the anal vein continued to the wing margin and with partly red colouration of the legs and abdomen. His species are classified into two sections, in the first of which there are four included, *P. betae, P. conformis, P. hyoscyami* and *P. haemorrhoum*, the last of Zetterstedt. The first

three of these are however synonyms for one and the same species. Pandellé (1907) considered *Pegomyia* as a sub-genus of *Anthomyia* giving the colour of the body as of sub-generic value, which is by no means satisfactory. Stein (1906), although admitting that the establishment of *Pegomyia* as a separate genus is quite artificial and untenable *stricto sensu,* yet adopts it in his scheme of classification. His reason for so doing is that the species included in the genus possess at least one plastic character in addition to colour, namely the quite regular absence of the cruciate bristles (Kreuzborster) in the female sex. In the few exceptions the presence of these bristles forms a very good specific character. In scrutinising the extent of the genus it is observed that Stein considered as belonging to *Pegomyia*, all Anthomyiids which have the antennary bristle naked, or at least slightly pubescent, eyes naked, always three dorso-central bristles behind the transverse suture, the anal vein continued to the margin of the wing and the tibiae yellow in at least the greater part.

3. *History of the Species.*

According to Westwood (1840) the larvae of *P. hyoscyami* are stated as devouring the parenchyma of the leaves of various plants, living between the two surfaces, but the author records no definite food plants. Zetterstedt in 1846 described the adult and quotes Wahlberg as having found several of the larvae in the parenchymatous tissue of the leaves of *Hyoscyamus niger* just before the plant flowered. Curtis in 1847 first recorded the var. *Anthomyia betae* as mining in the leaves of mangold-wurzel and quoted a short description of the larva. The author also described the adult male, the female being unknown to him. In his account the antennae and palpi are stated to be wholly black whereas the former have the basal segment more or less red and the latter have only the terminal segment black, the two basal segments being yellow as Meade later described. A doubt is expressed as to the extent of the damage caused by the maggots and a suggestion made that cattle eating the leaves containing them may be injuriously affected. In the following year (1848) Scholtz, in a paper on leaf-mining insects, has the following: "*Anth. betae* mihi (der *Anth. exilis* Meig., *versicolor* Meig., und *mitis* Fbr. verwandt) minirt nach meinen Beobachtungen in grössern Plätzen, die oft das ganze Blatt einnehmen, und zwar gesellig die Blätter von *Beta trigyna*." The author must have been unaware

that the name had been previously employed and the species described by Curtis.

In 1851, Goureau described the adult which he named *P. atriplicis* G. and called attention to the resemblance of the larvae to those found by Réaumur in the leaves of henbane. He reared his specimens from larvae which he found on the leaves of orache, *Atriplex hortensis*, and hence he named the fly " la Pegomyie de l'Arroche." The description of the larva is scanty, and that of the pupa, although brief, is the first record we have of this stage in the life-history of the species. Further he recorded and described a Braconid parasite which emerged from the puparium of the fly, and this he named *Alysia picta*. For the first time we meet with rather an interesting statement in this author's paper where he says that " la Pegomyie de l'Arroche " also attacks beetroot. This is a matter which will bear investigation as I am inclined to think that the species occurs in distinct " biologic species," each of which has its own food plant, and my experiments, although not by any means exhaustive, tend to support this fact. Guérin-Méneville in the same year (1851) described *P. atriplicis* R.-D. and states that in Goureau's collection this species is wrongly named *P. hyoscyami*, which he says is a distinct species. They are probably one and the same, as also the *P. Gouraldi* R.-D., which he also describes, seemingly from one immature specimen.

Nördlinger (1855) deals with the " Runkelfliege " (*Musca* (*Anth.*) *conformis* Fall.) and makes some very interesting observations on the life-history. He was the first to note the ornamental network on the chorion of the egg and he also attempted to determine the duration of the various stages in the development. Perhaps of most importance is his discovery of two broods of flies per year with perhaps a third in favourable climatic conditions. Comment is made on the backward growth of beet plants which are severely infested and on the difficulty of applying remedial measures. Taschenberg (1880) practically takes Nördlinger's description of the fly as well as his account of the life-history. He states that the development of the larva occupies a few weeks which, besides being rather indefinite, is inclined on the side of length. To compensate for damage caused by the pest he suggests that there should be no stinting in the amount of seed sown, a method which would have had little practical significance in combatting the enemy.

Schiner (1862) and Rondani (1864) give descriptions of *hyoscyami*, the latter employing the generic name *Chortophila*, and the only observation

that he makes of the larva is that he has on a few occasions seen it feeding between the two epiderms of the leaves of *Hyoscyamus niger* (henbane).

Kaltenbach (1874) records the larvae of *Anthomyia conformis* Mg. from *Chenopodium album* and *C. murale.* He also records the larvae of *A. betae* Scholtz from mangolds, those of *A. hyoscyami* Mg. and *A. nigritarsis* Zett. from *Hyoscyamus niger.* From henbane too he reared adults of *A. hyoscyami* R.-D., which he believes to be distinct from the *A. hyoscyami* of Meigen.

Farsky (1879) carried out some interesting experiments to determine the time occupied in the development of the egg, larva and pupa, but as the material was kept in glass-houses at a temperature much in excess of what would have normally prevailed outside, he recognised that the results were somewhat vitiated. For some reason or other which he could not explain he failed after several attempts to rear adults from first-brood larvae. With regard to the damage committed to beet crops, Farsky proved by direct experiment that those plants, the leaves of which had been mined, gave a markedly poorer yield when compared with that of unattacked plants. On an average he reckons that the beet plants which have been laid under toll by the pest have their polarisation affected adversely to the extent of two to four per cent. As preventive measures he advocates, like Nördlinger, an abundant sowing of seed with conditions kept fairly humid in the young stages of the plant's growth, and charcoal dust is said to be effective, but only to a small extent, in keeping the pest under control. Searching for the eggs on the leaves and their consequent destruction on being found is also of great utility.

Brischke (1880) in a most useful paper entitled " Die Blattminirer in Danzig's Umgebung," describes *Anthomyia femoralis* as a new species which he reared from *Chenopodium album,* but, except that the antennae are stated as being black, the description tallies with that of *hyoscyami,* with which it is agreed to be synonymous. The food plants of the polyphagous *hyoscyami* and its synonym *conformis* are also listed. Brischke attempts a rough classification of leaf-mining insects according to the mode of excavation of their galleries and the deposition of their excrement in the same.

Two Swedish entomologists, Holmgren (1880) and Tullgren (1905) have described the species from spinach, *Spinacia oleracea,* the former under the name of *Anthomyza spinaciae* (" Spenatflugen "), the latter employing Zetterstedt's name, *Anthomyia dissimilipes.* Besides spinach

Tullgren reared the fly from *Chenopodium album*. As remedial measures against the larvae, he advocates spraying the plants with a paraffin emulsion of the following composition ; 10 litres of paraffin, $\frac{1}{2}$ kilogram of soft-soap to 100 litres of water. Another method which he thinks might prove effective against the puparia in the soil is to spread the latter with soot, guano or superphosphate. Probably neither of these methods would prove very effective in combatting the pest.

In 1905 Professor Carpenter in Ireland reported the prevalence and ravages of *P. betae* in that country. In his account of the life-history he suggests the probability of there being four larval moults resulting in five stadia. As far as my own observations are concerned with *P. hyoscyami*, I think I may pretty safely say that there are not more than four stadia. The removal and burning of all affected leaves, as the author states, is an effective but laborious method, where large crops are involved, of temporarily minimising the ravages of the pest. Another and more practical method which he advises, consists in the application of a stimulating manure which, with a copious rain supply, would have the effect, at least in the young stage, of forcing the growth of the plant and strengthening it, the better to endure the attack of the maggots. As the author further observes, the affect on the yield of a mangold crop is most accentuated when the injury has been severe during the period when the young foliage has recently burst forth.

In America Chittenden (1903) deals briefly with the beet or spinach leaf-miner, *Pegomyia vicina* Lintn., and asserts that infestation of cultivated crops is often traceable to the negligent harbouring of weeds such as lambs-quarters which, the author says, fulfil the function of breeding-reserves on which the fly can always rely in times of need. As the fly is said to show a decided preference for spinach the author proposes its use as a trap crop in sugar-beet fields. Otherwise the methods of control are similar to those suggested by Professor Carpenter whose source of information is Chittenden's memoir.

4. *Distribution.*

This species is widely disseminated throughout Europe and is probably to be found wherever beet, spinach and mangolds are cultivated. Vassiliev (1913) records it from Russia and it is perhaps more prevalent in Northern (where these crops are more generally grown), than in Southern Europe Its ravages have been recorded from all over Great

Britain and Ireland and wherever mangolds are grown in this country it makes its presence felt.

In the collection of the British Museum (Natural History) there are specimens from the following localities in England:

W. Haddon, Rugby (W. Page); Newmarket, Walton-on-Naze, Slapton, S. Devon, Penzance (G. H. Verrall); Hastings (E. N. Bloomfield).

A better idea of its range is derived by consulting the reports of Miss Ormerod and Theobald, to which reference is made later.

In America its activities are practically confined to the New England States, and it has been recorded from Michigan. It also extends into Canada as Lochhead (1903) reports.

5. *Food Plants.*

The food plants of the species are distributed principally amongst the two orders Chenopodiaceae and Solanaceae. Brischke records it from a single example each of the Cruciferae, *Stellaria media*, and of the Polygonaceae, *Polygonum persicaria.* According to Goureau, Scholtz, Nördlinger, Kaltenbach, Brischke, Tullgren and Holmgren, the following are the host plants in Europe of *P. hyoscyami* and its synonyms.

Pegomyia hyoscyami Panz., Mg.
Hyoscyamus niger (henbane)
Pegomyia betae Scholtz, Curtis
Beta trigyna (beet), Hungary, Asia Minor
Beta vulgaris (common beet)
Beta vulgaris var. hybrida (mangold wurzel)
Pegomyia atriplicis Gour., Rob.-Desv.
Atriplex hortensis (orache)
Beta vulgaris (beet)
Pegomyia conformis, Mg., Fall., Nord., Zett.
Stellaria media (chickweed)
Chenopodium album (white goosefoot)
Chenopodium murale (nettle-leaved goosefoot)
Beta vulgaris (beet)
Polygonum persicaria (spotted persicaria)
Pegomyia Gouraldi Rob.-Desv.
Atriplex hortensis (orache)
Pegomyia femoralis Brischke
Chenopodium album (white goosefoot)
Pegomyia dissimilipes Zett.
Spinacia oleracea (spinach)
Pegomyia spinaciae Holmgr.
Spinacia oleracea (spinach)

Jablonowski (1909) makes two significant statements with regard to the food habits of the larvae of *P. hyoscyami.* If the natural food plants should by any chance fail the larvae may complete their development on a diet consisting either of manure or humous matter, and also on decaying leaves of any kind. This is a point of much importance as, in cases of exigency, the species is always more or less ensured of a means of subsistence. Referring to the larvae the author says (p. 310): "Gibt es für sie keine Wirtpflanzen mehr, so kann sie sich auch in diesem Falle helfen: findet sie kein ihr entsprechendes Blatt, so

lebt sie auch im gedüngten, oder im sehr humosen Boden (dies ist dann die *Anthomyia cunicularis* Rond)." Later (p. 313), he says: "Falls aber die eigenen Blätter der Rübe unzulanglich wären, finden sich wohl in der Nähe andere faulende Blätter, welche ihr ebenfalls zusagen. Die Fliegenmade bleibt in der einen, oder der anderen Weise doch immer am Leben und kann sich später in grösserer Anzahl vermehren."

6. *Description of the Leaf-Miner,* Pegomyia hyoscyami.

The adult (Pl. II, figs. 19, 20, 21, 22).

The following account has been borrowed and translated from Stein's paper on the genus *Pegomyia*, "Die mir bekannten europäischen Pegomyia-Arten," a very exhaustive and systematically arranged piece of work. The author points out that although enjoying a fairly wide distribution, the species cannot be designated a common one. The numerous synonyms applied to it are accounted for by the fact that the colour of the adult varies according to the life-history of the maggot, but in spite of this variation the plastic characters are so constant as to admit of the species being recognised with a fair amount of certainty. Stein distinguishes two varieties, *hyoscyami* Panz., the true species, light-coloured, and the darker form, *betae* Curt.

"The eyes, not very large, are almost equally broad above and below and are separated by a distinct stripe and the orbits. Frons projecting, cheeks small carinate, jowls rather broad, posterior aspect of the head convex below, bedusted all over silver-grey, on the cheeks close to the basal segment of the antennae a quite distinct, blackish, somewhat iridescent spot. Vertex as well as the median stripe generally blackish-red, also in some cases of a lighter shade, according to the age of the individual. Antennae incurving just below the middle of the eyes, shorter than the face, black, second segment more or less red, bristle naked, rather thickened at the base, palps thread-like, yellow, the terminal third segment black. Thorax, scutellum and abdomen in the lighter coloured form varying from pale to yellowish-grey, the former without perceptible striping; acrostichal bristles somewhat more closely set than the dorso-central, pre-alar small. The abdomen is sub-cylindrical, sometimes somewhat depressed and viewed obliquely from behind a small, pale brown median stripe is recognisable; the rather swollen hypopygium as well as the ventral lamellae (belly) is

often of a reddish colour, rarely the entire abdomen is of a brick red colour. Legs yellow, anterior femora with a more or less distinct, longitudinal streak, tarsi black, pulvilli and claws rather elongate. The investment of bristles does not present any special characteristic, only it might be noted that, of the bristles on the outer side of the posterior tibia, the one beneath is usually quite long. Wings pale yellowish, without costal spine, third and fourth longitudinal veins parallel, posterior cross vein steep and straight, the equally-sized squamae whitish-yellow, halteres yellow.

In the darker form the thorax and abdomen are of a more brownish colour and on the former there is seen posteriorly the faint trace of three somewhat dark longitudinal stripes. The abdomen as viewed from behind is thickly bedusted, pale brown and a fine dark dorsal line is relatively quite distinctly recognised; it is often interrupted at the posterior margin of the segments. The rather strikingly spherical hypopygium is bedusted just like the abdomen, sometimes overspread reddish, the ventral lamellae reddish. The colour of the legs varies; either only the anterior femora brown or also the middle and posterior femora completely or at least on their upper surface, although sometimes very indistinct.

The eyes of the female are more roundish, the broad frontal stripe reddish-yellow, sometimes somewhat obscured, the entire head either pale brown or reddish, palpi generally thickened at the extremity, club-shaped. Thorax grey or brownish-grey with the trace of a fine median stripe; sternopleural bristles 1·2, the lower posterior but considerably smaller than the upper, often only hair-like. In the matter of colour, the abdomen again very variable, either pale brown or brick red, sometimes a dusky red with the posterior margins of the segments a pale brick red. But in all cases there is faintly seen, when looked at quite obliquely from behind, a fine brownish or reddish longitudinal line. The legs are rarely entirely yellow, generally the anterior femora with a more or less evident longitudinal streak."

Length 5·8–6 mm. Wing 5·5 mm.

The egg (Pl. I, fig. 1).

The eggs are pure white, elongate oval, 0·87 mm. long × 0·31 mm.; surface not glistening, with a delicate sculpturing or pattern of irregular hexagonal areas on that side of the chorion distal from the leaf; surface attached to the leaf, plain; micropyle in a small depression at the apex.

The larva (Pl. I, fig. 2).

Larva, newly hatched, about 1·0 mm. in length, almost transparent, with mouth apparatus, tracheae and alimentary canal distinctly visible through the cuticle. Anal spiracles sessile with two slits apparently communicating, shaped like a semi-inverted ω, thus ϵ. Fleshy tubercles on the ultimate segment not very distinct. Anterior thoracic spiracles absent. Immediately before the first ecdysis the larva has increased its length to 1·6 mm.

The second instar larva (Pl. I, fig. 6), smooth, with a pair of prothoracic spiracles, one on each side of the post-cephalic segment and each divided into seven lobes. Posterior stigmata situated on the oblique dorsal position of the ultimate segment with two slits (Pl. I, fig. 7, *p.sp.*) just as in the first-stage larva, but constriction between the two now more accentuated, slightly elevated. Paired tubercles of the last segment are four in number (Pl. I. fig. 7), with rather a large but inconspicuous pair of flat adanal lobes (*a.l.*). On completion of the second stadium, the larva has almost doubled its size, now measuring 2·8–3 mm. in length. Following another ecdysis, the larva enters the third stadium when, except for size, it resembles in all respects the fully mature larva. Length 6 mm.

The full grown larva (Pl. I, fig. 2) averages about 7·5 mm. long and 1·8 mm. broad, with thirteen segments of which twelve are evident, of a dull yellowish colour, much wrinkled. On the cephalic segment immediately posterior to the mouth hooklets are situated the minute two-jointed antennae (Pl. I, fig. 4, *a.*), and slightly posterior to these again and placed somewhat nearer to each other, is a pair of sensory spots (*s.p.*). The prothoracic spiracles (figs. 2, 4, *pt.sp.*) quite distinct, with the number of lobes increased to eight. Definite areas on each segment bear minute, closely-set locomotory spines, arranged lineally in rows; on the first two segments posterior to the head the spinous areas are not so definite, but these bear anteriorly three or four regular rows of spines encircling the segments. Ultimate segment has the posterior aspect divided into two distinct areas, a dorsal oblique and a ventral truncated, bearing in all seven pairs of small tubercles (Pl. I, fig. 3) arranged as in figure. The pair lying immediately below the spiracles in the stigmatic field are slightly internal to the circumference of the circle formed by the others. Posterior spiracles (*p.sp.*) sub-sessile,

with three apertures clearly delimited, of which the two placed more dorsally are about half as far apart as the median and ventral.

There would appear to be much individual variation both in the size and structure of the mature larva. For instance Farsky (p. 111) states the size to be 7 mm. long and 1·7 mm. thick, and Professor Carpenter (p. 290) gives the length as being 8–10 mm. The latter also states that the prothoracic spiracles have eight to ten branches whereas I have only been able to observe eight in the full grown larvae. A possible explanation of such variations as being an expression of differences in the nature of the host plants, readily presents itself to our minds, and while Farsky's larvae were reared from beet leaves and Carpenter's from the leaves of mangolds, mine fed on the leaves of belladonna. It may be that we get distinct "biologic species" of flies according to the food plants which they patronise.

In a note which I have from Professor Carpenter, dated October 12th, 1912, the writer realises the probability of variation in definite species of dipterous maggots, but states also an interesting case of convergence where, if one takes a large series of larvae of *Lucilia Caesar* and *Calliphora erythrocephala*, distinctions which apparently hold good amongst a small number lose their value. His attention was drawn to this fact by Dr R. Stewart MacDougall.

The puparium (Pl. I, fig. 13).

Puparium measures 4·8–5 mm. in length, greatest breadth about 1·4–1·5 mm. Shape rectangular oval, narrowing sharply both anteriorly and posteriorly, sides slightly sinuate in outline, but not so markedly as in the puparium of *P. bicolor* (fig. 14). The rounded contour of the last segment interrupted by the slightly projecting posterior spiracles. Anterior spiracles less prominent with a lateral outward inclination. Scarcely a trace of the posterior tubercles of the larva. Segments distinct, demarcated by narrow striate bands of lineally and serially arranged spines, characteristic of the larval cuticle, as shown in the figure. The whole puparium as if lightly scarred or wrinkled, a condition due to the general contraction that occurred in the transformation from the larva. Colour at first pale ochreous yellow, gradually deepening through shades of red, reddish-brown to dark brown and brownish-black.

7. *Copulation, Oviposition and Egg Period.*

The Anthomyiidae are very restless active flies, and in captivity they seem to be endowed with such exuberance that they rarely become accustomed to the narrow confines of a wire-gauze breeding cage, such as was used throughout in the experimental rearing of *P. hyoscyami*. In many ways these roomy cages, as manufactured by Voss, commend themselves for observational purposes, built as they are of stout sheet iron, with sides of wire gauze, back wall and sloping roof of iron and with a glass panel front. On one side there is a hinged door and basally a detachable, well-fitting tray of zinc for containing soil, into which the fully mature larva of the species in question burrows previous to pupating. A potted plant of belladonna (the host plant of *P. hyoscyami*) was introduced into the cage and periodically watered to maintain its freshness and ensure its growth. The stout heavy basal part of the cage may be detached from the upper, lighter portion by the removal of two small, bent, iron rods, one on each side, fitting closely into hollow projecting iron cylinders placed alternately on the upper edge of the basal and the lower edge of the upper part. When in position these rods fix the two parts of the cage firmly together.

Copulation takes place after the lapse of a number of days from the time of exit of the female from the pupa case. This interval is determined by one or more factors, such as the constitution of the female, the kind of nutrition and the amount of food, the time of year, and the prevailing weather conditions. For instance in the breeding cages kept in the insectary which had free access to daylight and where the conditions were, as nearly as possible, similar to those in the open, the flies were never observed to copulate when the sky was overclouded. Indeed, in the summer and autumn of 1912, owing to some reason or other, copulation never occurred in the cages and consequently no eggs were laid. Never yet has it been my good fortune to observe the act of pairing outside, but on Aug. 26th, 1913, the behaviour of the flies in this respect was noted for the first time and the accompanying sketch (Text-fig. 1) drawn from life.

As represented in the figure, the male stands above the female with its fore tarsi applied to the thorax and resting on the shoulders of the wings which are kept divaricate. The middle tarsi of the male embrace laterally the fifth abdominal segment of the female, whilst the hind tarsi encircle the extremity of the latter's abdomen. The femora and tibiae

of the middle and hind legs of the male are hunched up, the femora ascending backwardly and the tibiae descending forwardly making a sharply acute angle with the femora. The head of the male extends forward above the level of the scutellum. The ventral side of the male's thorax rests upon the dorsal region of the female's abdomen, and the concave ventral surface of the male abdomen arches round the convex dorsal surface of the female's in such a manner that the hypopygium (the modified ninth abdominal segment) of the male with its claspers and intromittent organ extends under the extremity of the female abdomen and is closely applied to the latter for purposes of coition.

The act of pairing continues for about half an hour and even longer, and, if disturbed, the female endeavours to liberate itself by pressing

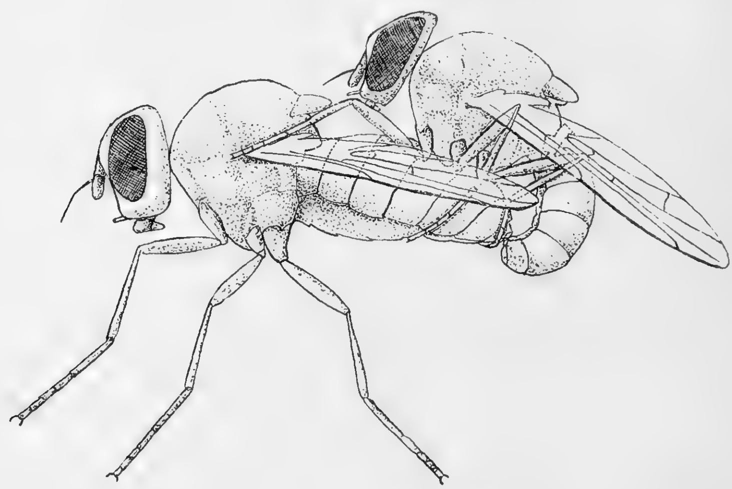

Fig. 1. *Pegomyia hyoscyami* in copulation. The investing bristles are omitted. × 12.

with its posterior tarsi against the tarsi of the male, in its attempt to loosen them.

Martelli (1908) in his paper "Altre Notizie Dietologiche della Mosca delle Olive," p. 93, describes copulation in *Dacus oleae*. The position adopted by the male of this species is quite different from that of *P. hyoscyami* owing to the female's having a long, exserted ovipositor, which is general in the Trypetidae. In this case the anterior tarsi of the male embrace laterally the first abdominal segment of the female, while the others rest upon the ground.

Oviposition does not always take place immediately after copulation, and indeed all evidence points to the necessity of an interval of one or

more days. The female lays the eggs (Text-fig. 2) superficially on the under side of the leaf (only once have I observed the eggs on the upper surface), generally in neat, parallel rows, the eggs of any one row being closely applied to each other laterally and seemingly held together by a kind of cement which also serves to attach the eggs to the leaf surface. A good idea of what is meant will be obtained from the figure. The number of eggs in any one row as well as the number forming an egg-group varies. All sorts of combinations may be got. The number may be as low as one or two and there may be as many as fifteen or twenty, and even more. On the same leaf, apparently depending on

Fig. 2. Eggs of *Pegomyia hyoscyami* on under surface of a belladonna leaf. ×9.

its size, there is often more than one group of eggs and rare cases of three or four are recorded. The flies seem to show a preference for the leaves of the top shoots, but later on in the season the radical leaves become quite as badly attacked.

The eggs hatch in from four to five days, but as long an interval as five to six days has been recorded. Farsky (p. 109) states the period to be six to eight days in the case of the synonym, *P. conformis*, and

Chittenden (p. 51), quoting Howard, gives it as three to four days in the case of the synonym *P. vicina*. The time will vary according to the weather conditions and temperature, and to the degree of exposure of the eggs on the various leaves. In the laboratory where a temperature of 70° F. was maintained, the eggs hatched usually after the short interval of three days.

In order to get an approximately accurate idea of the duration of the egg period, the belladonna host plant was kept under close observation in the open. As soon as a leaf was noted with eggs newly deposited, a tag-label bearing the date was attached to the stem immediately below the leaf petiole and numbered. From time to time the leaves thus marked were closely examined. A fairly exact idea was thus obtained of the time occupied in the development of the embryo within the egg. Some of the results are appended in Table I :

TABLE I. Pegomyia hyoscyami *and its oviposition.*

Number of Experiment	Date of Oviposition	Number of Eggs in a Group	Date of Hatching of First Egg	Number of Days
1	24th June	4	29th June	5
2	24th ,,	6	30th ,,	6
3	25th ,,	12	1st July	6
4	26th ,,	8	30th June	4
5	27th ,,	11	3rd July	6
6	28th ,,	14	4th ,,	6
7	28th ,,	13	3rd ,,	5
8	28th ,,	9	3rd ,,	5
9	29th ,,	8	4th ,,	5
10	30th ,,	7	4th ,,	4

It must be observed that the larvae generally hatched in the cool of the evening, and in a few cases the emergence of the larva occurred during the night. In these latter the time could only be guessed at, but with quite a close approximation to the truth since an indication would generally be got of the time that the larva had abandoned the egg, from the progress which it had made with its gallery beneath the epiderm. The eggs of any one group do not hatch synchronously, but the variation in time is often only one of minutes. As long as twenty-four hours between the hatching of the first and last eggs have been noted. Later in the season, towards the end of September, a single case where the eggs took eight days to hatch was recorded.

The number of eggs which any one individual will deposit cannot

be definitely stated, but a reference to my notes reveals the case of one female which laid first eleven eggs and then proceeded to deposit two more groups of twelve and nine. The probability is that even then she had not finished. Perhaps forty would be a very low estimate. In an examination of a fertilised female about one hundred and forty ova, of which twenty-two were ready for oviposition, were discovered in the egg-tubes and uterus.

Habits of larva, duration of the various larval stadia, pupal period.

The behaviour of the larva within the epiderm of the leaf has been fully dealt with by Farsky (pp. 109–110) in the case of *P. conformis* mining beet leaves and what is said there holds good for the larvae of *P. hyoscyami* in belladonna leaves. Réaumur has also given a detailed description for the larvae mining in the leaves of *Hyoscyamus niger*, and my observations practically agree with theirs.

The young larva makes its exit from the egg by a small circular aperture at the micropylar end. Operations on the leaf epiderm are immediately commenced with a view to an entrance to the underlying mesophyll layers, but at this time its actions are not characterised by excessive energy. The egg-shell collapses when the larva has abandoned it, and a small quantity of frass, the excrement of the tiny maggot as it burrows into the leaf, is left behind. It would appear that an ecdysis occurs on the exit of the embryo from the egg. In all cases where evacuated eggs were examined, a very thin, transparent, delicate membrane was persistently found adhering to the internal walls of the chorion. The whole process of the larval emergence is a progressive one. The larva, by eating its way into the parenchyma, makes a gallery for itself, increases its size, and by bodily extension, rends the egg-shell longitudinally and ventrally. The migration from the egg to the parenchyma is stated by Farsky (p. 109) to occupy a whole day, if the weather conditions are favourable; if adverse, the operation occupies two to three days, whilst excessive moisture induces abortion.

Where a large number of eggs are present on one leaf, it is often impossible for all the emerging larvae to find subsistence thereon, and consequently many are sacrificed. On several occasions it was observed that when two or three batches of eggs were deposited on a single leaf, only a few larvae succeeded in attaining maturity. Should a comparatively long interval elapse between the times of emergence of the larvae from the different egg-bundles, those which hatch earliest stand

the best chance of completing their development. If, in the course of their activities, they undermine the mesophyll layers beneath a bundle of unhatched eggs, the larvae issuing from the latter do not attempt to enter the leaf where the epiderm has been loosened, but they search about for a part that is fresh and untouched. Often they die before they succeed in fulfilling their mission, and, indeed, sometimes the eggs do not hatch at all. The exact reason for this it is not easy to find. Perhaps it may be that they merely undergo desiccation owing to the discontinuance of the respiratory functions of the injured part of the leaf. The incurrent and excurrent streaming of moisture-bearing gases through the leaf-stomata, which would, in the natural course of events, maintain an atmosphere sufficiently humid for the successful development of the embryo in the egg is totally checked, with fatal results.

No definite information has been previously given of the duration of the various larval stages of which there are undoubtedly three, and the statements also of the different authors of the length of the complete larval and pupal stages are apparently in disagreement. But this seeming inconsistency is quite comprehensible when one considers that the times may vary in multi-brooded species depending on the season, according as it is the first, second or third brood, and further because of the climatological conditions which prevail in different countries as well as in different districts of the same country.

As indicated previously in the description of the larva, there are at least two moults and three distinct stadia. Carpenter (p. 290) suggests the probability of there being four moults, but I have not been able to verify this additional one which he assumes as intervening in the last larval stadium. During the month of June the larva completed its development in about ten days. Later in the year, during September, as many as twelve days were required. Where incidental circumstances are favourable, the times of the various larval stages are approximately twenty-four hours for the first, forty-eight hours for the second and seven days for the third.

It is interesting to note the time occupied by the larvae of the different stages in making an entrance into a fresh leaf when placed upon its surface. In some cases they get to work rapidly. Often they keep wandering restlessly here and there. The following are three authenticated cases, the facts of which were noted on June 23rd.

(1) Three larvae recently emerged were removed to a fresh leaf. After a few sluggish efforts to pierce the epiderm, which occupied an hour, they gave up the attempt. Even when a tiny puncture was

made for them with the point of a needle they achieved no progress and finally died in about an hour and a half.

(2) A larva in its second stage was similarly treated. After moving about actively for about a quarter of an hour, it seemed to find a spot to its liking. Working vigorously it first made a small slit in the epiderm which it enlarged to a circular aperture by an unflagging series of to and fro, semi-rotatory movements of its mouth hooks. In two hours and twenty minutes it had disappeared completely from view in the gallery which it had eaten out.

(3) A larva of the third stadium, recently moulted, accomplished the same performance in the comparatively short space of twenty-five minutes.

The pupal stage extends over a period of about two or three weeks, and sometimes longer. Nördlinger (1885) believes the pupal stage occupies fourteen days, whilst Taschenberg (1880) gives as low an estimate as ten days, which is in accord with the ten to twelve days cited by Jablonowski (1905). The insects hibernate in the soil as puparia. Several larvae, collected during October, assumed the resting condition on the 20th of this month, and from one of the puparia which were kept amongst damp sand in a cool-house, an adult emerged on May 24th of the following year, representing the elapse of one hundred and fourteen days.

The adult period, length of life-cycle.

When the fly is ready to emerge it bursts open the retaining pupa-case anteriorly by means of the pressure of the exserted ptilinum and makes its exit through the resulting T-shaped cleavage. The animal does not at once assume its final, natural colour. The thorax is pale, cinereous, whilst the legs and abdomen are pale yellowish. Having finally rid itself of the puparium, the imago remains resting for a time during which the ptilinum is periodically inflated. This action together with a peristaltic movement of the abdomen, is associated with an apparent growth in size of the fly and also with the expansion of the wings hitherto neatly folded up and closely applied to the body. The wings take about three minutes to expand completely, the extremities unfolding first. All the time the colour is becoming darker.

There is then a period of apparent rest when the various regions of the body assume their normal shape, and the cuticle hardens. The wings are slightly raised and become more transparent. The frontal

region of the head loses its flexibility, and becomes more or less rounded. There is then a period of contraction when the fly remains motionless. The abdomen shortens gradually until it has attained its natural size, whilst the head and thorax also become visibly smaller. By this time all the parts have assumed their fundamental colours. The complete operation occupies about an hour.

The adults live for about two weeks but, in confinement, when fed on a solution of sugar, they will live for as long as three weeks.

From a consideration of the foregoing remarks on the life-history of *P. hyoscyami*, a fairly definite idea may be got of the time that elapses for the various stages of development in the north of England during midsummer :

		DAYS
Time intervening between the issue of the adult and oviposition		4
Egg period		5
Larval period		
First stadium	24 hours	10
Second ,, ...	48 hours	
Third ,, ...	7 days	
Pupal period		17
Average time for one brood		36

There are at least three broods per annum, but there is a good deal of overlapping of the various stages owing to differences in the times of emergence so that eggs, larvae, pupae and adults are all found to occur simultaneously from June to September.

8. *The Buccal-Pharyngeal Apparatus.*

The complete masticating apparatus of the mature larva of *P. hyoscyami* (Pl. I, fig. 15) consists of a number of paired sclerites, the members of each side articulating with one another to form a united whole. In the younger larval stages the form of the apparatus is essentially similar to that of the fully-developed larva, the difference being one of degree and not of kind. Each moult sees a strengthening of the chitinous structure.

The strong tooth-like hooks which are seen projecting when the larva is feeding are the mandibular sclerites (*md.s.*) provided ventro-laterally with four small teeth and with a blunted dentate process

ventro-posteriorly. Basally each is perforated by a tiny pore. The dentate sclerites which articulate ventrally with the posterior halves of the mandibular sclerites of the larva of *Anthomyia radicum*, as Hewitt figures (Pl. II, fig. 7, *d.s.*), are here absent. Articulating posteriorly with the mandibular sclerites are the hypostomal sclerites (*h.s.*) united to each other by a slender rod, not evident in a lateral view. Each individual of this pair somewhat resembles a short dirk. From the angle formed by the handle and the blade there proceeds a delicate, slender rod (*i.s.*) which articulates with the broad, ventral, posterior process of the mandibular sclerite. The proximal extremities of the two hypostomal sclerites articulate, one on each side, with the distal ends of the cephalo-pharyngeal sclerites (*c.p.s.*) which have each a slight anterior, ventral, ploughshare-like continuation joining on to the hypostomal sclerite of its side. The cephalo-pharyngeal sclerites are broadly and deeply embayed posteriorly, thus forming a dorsal (*d.p.*) and a stout ventral process (*v.p.*). The latter is provided posteriorly with a dorsally directed blunt process. The dorsal arm of the cephalo-pharyngeal sclerite is itself bifurcate, so that a slender ventral process directed posteriorly underlies the broader dorsal process. Finally the perforate sclerite (*pf.s.*) situated dorso-anteriorly between the cephalo-pharyngeal sclerites, serves to unite them. In the figure it would appear to be quite detached. This displacement is caused by the pressure of the cover-slip on the mounted preparation from which the drawing was made. Midway between the ventral arms of the cephalo-pharyngeal sclerites there is situated a carinate sclerite of very slender proportions.

In Carpenter's figure of the mouth apparatus of the mature larva the cephalo-pharyngeal sclerite is represented as having quite a pronounced rectangular continuation anteriorly, where it articulates with the hypostomal sclerite. This gives one the impression of a foreshortening of the latter. In reality the suture is placed rather more posteriorly and the apparent continuation of the cephalo-pharyngeal sclerite belongs to the hypostomal.

9. *Comparison with* Pegomyia bicolor *Wied. and* Pegomyia nigritarsis *Zett.*

The two allied species *P. bicolor* and *P. nigritarsis* mine the leaves of *Rumex obtusifolius* and *Rumex crispus* in their larval stages, and their life-histories are practically identical and concurrent with that of *P. hyoscyami*. As imagos all three species have the same general facies

so that it is of interest to find that the larvae can be quite easily distinguished as also the puparia. It is almost impossible to find any distinguishing feature in the eggs of the three species. In each case the chorion has the same hexagonal pattern, but generally the sculpturing is more delicate on the eggs of *hyoscyami* (Pl. I, fig. 1) than on those of the other two, *bicolor* and *nigritarsis*. We realise however that this character is insignificant and unimportant, inclined as it is to much variation.

The following table is a *résumé* of the distinctive characters of the larvae, by which the three species may be separated and recognised in the larval condition :

Larval Character	*P. hyoscyami*	*P. bicolor*	*P. nigritarsis*
Integument	Wrinkled No post-cephalic ventral tubercle (" foot ")	Smooth, tough Post-cephalic ventral tubercle present (fig. 8, *a.p.*)	Smooth Absent
Colour	Dull, yellowish-white	Yellowish, iridescent	Dull white
Length	8 mm.	10 mm.	9·5 mm.
Anterior spiracles ..	8 lobes (Pl. I, fig. 5) Palmate	25–30 lobes (Pl. I, fig. 11) Ellipsoidal	16–25 lobes Semi-ellipsoidal
Posterior spiracles ..	Sub-sessile (Pl. I, fig. 3, *p.sp.*) 3 apertures broadly oval, equidistant, of equal size (Pl. I, fig. 3)	Porrect, prominent stigmatic projection, 2-segmented (Pl. I, figs. 8, 9, *p.sp.*) 3 apertures, elongate oval, acuminate; equidistant (Pl. I, fig. 9)	Slightly projecting (Pl. I, fig. 12, *p.sp.*) 3 apertures, elongate oval, the largest dorsal, separate; twice the distance between the dorsal and the median as between the median and the ventral (Pl. I, fig. 12)
Tubercles of Ultimate Segment	7 pairs (Pl. I, fig. 3)	3 pairs—adanal lobes (Pl. I, fig. 9)	6 pairs, of which 2*a* and 3*a* placed posteriorly (Pl. I, fig. 12)
Antennae and Sense-organs	Sense-organs not so widely separate as the antennae (Pl. I, fig. 4)	Sense-organs almost adjacent, antennae separate	Sense-organs have same distance apart as antennae; situated nearer the antennae than is the case in *bicolor*

Nathan Banks (1912) describes and figures only twelve lobes to the prothoracic spiracles of *bicolor*, but careful examination of *bona-fide* specimens has always shown the presence of at least twenty-five lobes.

As the puparium, which represents the shrunk larval integument, retains the external characters of the larva in greater or less degree, though not always so prominent, the same distinctions thus hold good for the resting, as for the active, larval stage.

The mouth apparatus is of the same general formation in all three species, with the component sclerites practically similar in shape. They only differ in quite small details almost negligible for purposes of classification. A comparison of the cephalo-pharyngeal sclerites of *hyoscyami* and *bicolor* shows that the upper subtended process of the dorsal arm is relatively broader in the latter species (Pl. I, figs. 15, 16 and 17, *d.p.*). In *bicolor* the angle formed by the hypostomal and interstitial sclerites is more acute than is the case in *hyoscyami*, which is 45°. Further, the mandibular sclerites of *bicolor* bear dorso-posteriorly a small, backward-curving denticular process (Pl. I, fig. 17, *d.p.*), absent in those of *hyoscyami*, which aids in forming a concavity for the articulation of the distal extremities of the hypostomal sclerites. Again the teeth or denticles borne by the mandibular sclerites of *hyoscyami* arise more laterally than those of *bicolor*. The relation of parts is practically the same in *bicolor* and *nigritarsis*.

These generalisations have been made on the evidence of numerous specimens carefully examined, but I quite realise that the characters may not be absolutely stable. In some cases as will be seen from the foregoing remarks, the distinction of the species has a negative basis, depending on the presence of some detail in one species which is absent in another. This is often very useful for classificatory purposes, but either the specimens must be examined fresh or precautions taken that those examined have been well preserved.

10. *Remedies in England.*

Miss Ormerod collected much valuable information about the infestations of the mangold fly, which was incorporated in her reports of the years 1880–95. Severe attacks were recorded periodically from all parts of England, Ireland and Wales, from Cumberland and Westmorland in the north, where the species was first recognised about 1876 as a serious pest of mangolds in this country, to Devon and Cornwall in the south-west. The years 1880 and 1891 were notable for the great amount of damage done to this crop which was in many cases practically sacrificed to the ravages of the leaf-mining maggot. The same author also noted that the incidence of the fly was generally associated with the use of farmyard manure as a crop stimulant, especially when

applied in the spring, immediately previous to the sowing of the seed. Autumn manuring, as soon after the harvest as possible, is therefore advised, a course which Jablonowski (1909) also recommended in the cultivation of the beet. The manure is thus given a chance to decay and sink well into the soil during the winter months with the result that the fly is not attracted by it to the same extent as it would be by fresh dung.

The greatest and most lasting damage is usually committed by the mangold maggot at the seedling stages of the plants soon after they have been singled out. Thus a system of manuring which forces on the growth of the crop beyond this susceptible period, proves of much advantage in staving off ultimate disaster. To accomplish this Miss Ormerod found that the application of sodium nitrate in the proportion of about two-hundredweight to the acre produced desirable results. The only drawback is that, unless there be sufficient rain to wash the fertiliser down to the roots, its value as a stimulating agent is vastly reduced and almost negligible. Dressings of salt, potash and superphosphate introduced to the soil along with the seed have often proved beneficial. Where clean culture is practised and where the crop is grown in situations favourable to growth the loss incurred from the ravages of the maggot is not very appreciable. When neglected, the crop simply perishes from exhaustion in consequence of the leaves being killed off by the maggots more rapidly than the plant can replace them.

Spraying the infected crops with paraffin emulsion is another method which was brought to Miss Ormerod's notice (1885, p. 68) as an efficient remedy. The insecticide is made up in the proportions of 8 parts of water to 1 part of soft soap with $4\frac{1}{2}$ parts of paraffin added to the first two of these ingredients which have been previously mixed and boiled. A homogeneous mixture is thus obtained, and 1 part of the emulsion combined with 4 parts of water is said to prove quite effective in killing off the maggot.

Theobald also deals with the occurrence of the fly in this country in his reports 1909–11, and the same methods of combatting its attacks are recommended as those given by Miss Ormerod. This author also states that deep ploughing after an attack of the maggot will bury the puparia in the soil, thus rendering the emergence of the fly to the surface a difficult one. But I should imagine that where the soil is inclined to be heavy, forming clods instead of a fine tilth, the adults will generally succeed in making their way up, so that this method would only prove of utility in the case of light soils.

In carrying out experiments with the maggot which mines in the leaves of the belladonna, I found that an emulsion consisting of nicotine, paraffin and soft soap with water would at least check virulent attacks, and, if applied to the plants early in the season, it proved an excellent preventive against the fly ovipositing. The fully developed larvae did not seem to experience much inconvenience from contact with the insecticide, which is prepared as follows: to four parts of soft soap two pints of paraffin are added, and the mixture brought to the boiling

Fig. 3. Belladona plant used in breeding experiments of *Pegomyia hyoscyami*. Appearance after attack.

point. A small quantity of boiling water is then stirred in, and the whole then well mixed until a good emulsion is obtained. Four ounces of 95 % pure nicotine are then added. After thoroughly mixing the volume is increased to 100 gallons by the addition of more water. If poured into a drum and kept well corked the mixture can be stored and used at any time. The insecticide should be administered as a fine spray by means of a nozzle of the improved Vermorel or other makes, care being taken that both the upper and under surfaces of the leaves

are drenched. It penetrates the epiderm where the latter has become detached from the parenchyma and is most effective against the larvae of the younger stages. The best results are achieved if the nicotine-paraffin-emulsion is delivered to the plants just before the flies may be expected to oviposit as it wards off the adults. Frequent sprayings should be made in order to keep the pest under control. The cost works out at about 3*s*. 9*d*. per 100 gallons of the mixture.

11. *Natural Enemies of the Belladonna Leaf-Miner.*

Three species of parasitic Hymenoptera were reared from the puparia of *hyoscyami*. Of these two are Braconids belonging to the genus *Opius* and one of them is *Opius nitidulator* Nees ; Pl. I, fig. 23 represents

Fig. 4. *Opius nitidulator* Nees. Parasite of *Pegomyia hyoscyami*. Also parasitised puparia of *Pegomyia* showing the ragged edges where the parasites have emerged.

the fully developed larva of the latter dissected out from the puparium of its host. The third is a Proctotrypid, probably a hyperparasite of one or other of the two species of *Opius*, or perhaps of both. It was comparatively rare. The percentage of parasitism is rather high and, as the season advances, increases in intensity until the beginning of September, when it suffers a diminution.

Examination of larvae and puparia collected towards the end of this month and during October revealed very few parasites, a fact which may be associated with the diminution in temperature experienced in the autumn. This is borne out by the fact that the parasites are not so

prevalent when the first brood of the leaf-miner is on the wing as during the occurrence of the two subsequent generations, showing that the hibernating pupae had not been heavily attacked.

Continued spells of cool, damp weather are believed to have the effect of reducing the number of parasites, but this was certainly not very marked during the wet summer of 1912. The percentage was only slightly less than that of the following year, when more favourable conditions prevailed. This fact will be seen by consulting Table II, which shows the number of parasites that emerged from infested leaves collected in the field and kept either in breeding jars or cages in the laboratory :

TABLE II. Pegomyia hyoscyami *and its parasites at Fallowfield, Manchester, in* 1912 *and* 1913.

Month leaves were collected	Locality	Experiment No.	No. of *Pegomyia* emerged	No. of parasites emerged	% of parasites to total insects emerging
July 1912	Fallowfield	1	86	18	17
Aug. ,,	,,	2	24	6	20
Sept. ,,	,,	3	37	21	36
	Total ..	.. ..	147	45	23·4
July 1913	Fallowfield	1	36	6	14
Aug. ,,	,,	2	88	27	23
Sept. ,,	,,	3	41	32	43
	Total ..	.. ..	165	65	28·2

12. *Relation of* Pegomyia hyoscyami *to its Host Plants.*

Random statements are often made by entomologists of the migration of herbivorous insects from one host plant to another, and, although there are well-authenticated cases of certain species becoming serious pests by deserting common weeds to infest cultivated crops which are closely related, I am not at all convinced that this transition always takes place with that abrupt suddenness which many authors assume.

To determine whether adults of *P. hyoscyami*, reared from larvae which had fed on belladonna leaves, would oviposit on the leaves of mangold wurzel, a large number of fertilised females were confined in breeding cages along with fresh mangold plants, but the results were purely negative. In no single instance were eggs deposited. These experiments were repeated with fertilised females reared from mangold

feeding maggots and liberated in cages containing potted plants of belladonna. Again the results were quite negative. From the slight evidence thus obtained one would not be prepared to jump at a general conclusion, but it may just be possible that within the limits of a single polyphagous species, certain well-defined " biologic " species may be established, each of which shows a marked tendency towards one of their food plants. Consequent on this preferential adoption of a host, slight variations may arise such as in the colour, a fact which at one time led to the establishment of the variety *betae* as a species distinct from *hyoscyami*. As has been already noticed the imagos of *hyoscyami*, the larvae of which have had henbane and belladonna for food plants, are distinctly lighter in colour when compared with those the larvae of which have fed on the leaves of beet and mangold.

At Dartford in Kent, where henbane and belladonna are grown on a large scale for the sake of their alkaloid bases, it has been found that, whereas in some years as much as 80 per cent. of damage is done to the former crop by the maggot, the latter remains unaffected, although in close proximity. It would appear that the fly has become thoroughly established on the henbane to the exclusion of the allied belladonna. Of course, it may be that some definite organic substance specific to henbane and not present in belladonna is chemotropic to the fly, which would account for its ovipositing on the one host rather than on the other. When henbane is absent belladonna proves quite attractive.

Much interest, again, is derived from the question why *P. hyoscyami* should select members of the widely different families of Chenopodiaceae (beet, mangold) and Solanaceae (henbane, belladonna) as its host plants. Is it possible that they all exert the same sort of chemical stimulus inducing the one species to oviposit on any of them? Dr Trägårdh (p. 116) says: " If the food of the larva consists of several species of one and the same genus, or of different genera within one or several families, then it is an organic union, or group of such, common to all these, to which the species reacts positively." Again he says (*ibid.*): " The odour of organic matters [*to which the flies orient themselves and are attracted*[1]] is due to the occurrence of certain specific chemical combinations, *e.g.* organic acids, amines, terebines, phenols, glycosides, etc. which are characterised by a certain structure and stratification of the atoms." One can easily perceive the validity of the argument where one is confined to a consideration of a single vegetable

[1] The italics are mine (A. E. C.).

family, but in the present case of the two families Chenopodiaceae and Solanaceae, it lays itself rather open to attack, unless one extends the content of "specific chemical stimulus" to mean not merely that exerted by any one organic substance, but rather by certain of them which have similar groupings of their component atoms (*i.e.* specific *kind* of chemical stimulus). Such for instance are the nitrogen bases of which betaine, guanine, hyoxanthine in the beet, atropine in the belladonna, and hyoscine and hyoscyamine in henbane, all possessing marked physiological or toxic properties, are well-known examples. But it must not be inferred that these substances are attractive to *P. hyoscyami*, for there is no direct proof on this point, but, hypothetically, their presence in these different plant species would satisfactorily explain the varied food habits of the larva.

Since completing this paper, Dr Imms suggests to me the possibility of *betae* being one species confined to the Chenopodiaceae and *hyoscyami* a second species confined to the Solanaceae. The possibility of their being physiological species, which have undergone more or less morphological separation, appears to him as well as to myself, on the sum total of evidence, to be quite a feasible and justifiable proposition.

Summary.

The species *P. hyoscyami* has been recorded at various times by various authors, and it has often been described under different names, partly because of its having been reared from a fairly wide range of food plants. The belladonna leaf-miner is the larva of this species, found during the summer throughout Europe, United States of America and Canada.

The injury to the plant consists in the destruction of the parenchyma which the maggot greedily devours, the leaves assuming a blistered appearance in consequence. The leaves thus attacked quickly flag and wither during dry weather. In this way excessive damage to the various food plants often results in their total loss, heavily affecting the agriculturist pecuniarily where they are grown as cultivated crops.

Other food plants besides belladonna are mangolds, beet and henbane.

The number of the larvae in one leaf varies with the size of the latter and, roughly speaking, directly as the size.

The ravages are periodic and often quite localised, resulting in diminished yields of the products of the different crops attacked. The

top shoots are most heavily infested early in the season, but later the radical leaves are most attacked.

Hibernation occurs in the pupal condition about two inches below the surface of the soil near the food plants.

The number of broods vary. There are at least three in latitude. The broods are not separated sharply off from each other. There is a good deal of overlapping so that all stages occur in the field during the greater part of the season.

The eggs are deposited superficially on the back of the leaf in groups consisting of parallel series varying in number. The incubation period is about 5 days.

The larvae feed uninterruptedly and complete their metamorphosis in 10 days under the most favourable circumstances. The larvae of the first two broods sometimes pupate in the leaf, generally making their way to the margin to do so. The pupal period of the first two broods is about 17 days.

The average period for one complete life-cycle is about 36 days.

Two closely related species, *P. bicolor* and *P. nigritarsis*, attack common weeds such as dock. Their life-histories are, in all details, almost similar to that of *P. hyoscyami*. Structurally, there are some interesting differences, especially in the larval stages.

According to the different food plants which it affects, *hyoscyami* may be divided up into at least two "biologic" species, one of which would seem to confine its energies to a few members of the Chenopodiaceae, the other to Solanaceae, and within these two families preferences to different species are shown. But in the absence of the one favoured food plant, another, not ordinarily so attractive, may be selected.

Species of the Chenopodiaceae and Solanaceae have in common certain specific organic substances belonging to the group known as the alkaloid bases. They probably serve as an attraction to the fertilised females to oviposit on the leaves of the plants which contain the active principles concerned.

Experiments showed that mangold-reared adults would not oviposit on belladonna and *vice versa*. This restriction to one kind of plant is indirectly advantageous to the agriculturist in that strains of flies reared on belladonna confine themselves probably to this species or one closely related, such as henbane, and do not attack mangolds.

The young plants are more easily killed than the more advanced ones.

Natural control of the pest is secured by the parasitism of two species of Braconids on one or both of which a Proctotrypid is probably hyperparasitic.

The degree of parasitism ascends to a climax at the end of August and beginning of September, and then suddenly diminishes.

Frequent hand-picking of attacked leaves and their destruction provides a ready and effective means of killing the maggot and unhatched eggs. This method is only practicable where the crop is a small one.

Dressings of stimulating, chemical manures in the early stages, strengthens the plants so that they maintain themselves the better against the injurious effects of infestation.

Farmyard manure which attracts the flies should where used be applied in the autumn to give it the chance of decaying before the adults appear in the spring.

Deep-ploughing in the autumn serves to bury the hibernating puparia which lie near the surface, thus rendering the emergence of the adults in the spring a matter of comparative difficulty.

Paraffin emulsion is not so effective in killing the maggot as this same emulsion with nicotine added.

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EXPLANATION OF PLATES I AND II.

[For purposes of reproduction it has been necessary to reduce the size of the figures by $\frac{1}{5}$th. The magnifications given refer to the author's original drawings. *Eds.*]

Fig. 1. Dorsal aspect of the egg of *Pegomyia hyoscyami.* $\times 80$.

Fig. 2. Mature larva of *P. hyoscyami.* $\times 10{\cdot}5$. *pt.sp.* prothoracic spiracle.

Fig. 3. Posterior aspect of ultimate segment of same to show the position of the tubercles and the posterior stigmata (*p.sp.*). *an.* anus (highly magnified).

Fig 4. The three first segments of same, ventral aspect. $\times 15$. *s.p.* sensory papilla; *a.* antenna; *md.s.* mandibular sclerite; *pt.sp.* prothoracic spiracle.

Fig. 5. Prothoracic spiracle of mature larva (very highly magnified).

Fig. 6. Larva of second stadium. $\times 23$.

Fig. 7. Posterior aspect of ultimate segment of same to show the tubercles and posterior stigmata (*p.sp.*). $\times 34$. *an.* anus; *a.l.* adanal lobes.

Fig. 8. Mature larva of *Pegomyia bicolor.* $\times 10 \cdot 5$. *pt.sp.* prothoracic spiracle; *p.sp.* posterior spiracle; *a.p.* anterior ventral protuberance ("foot").

Fig. 9. Posterior aspect of ultimate segment of same, showing arrangement of tubercles and posterior spiracles (*p.sp.*). $\times 11$. *a.l.* adanal lobes; *an.* anus.

Fig. 10. Larva of second stadium of same. $\times 27$. *p.sp.* posterior spiracles.

Fig. 11. Prothoracic spiracle of mature larva of *Pegomyia bicolor* (highly magnified).

Fig. 12. Posterior aspect of ultimate segment of mature larva of *Pegomyia nigritarsis.* Tubercles are numbered; *2a*, *3a* placed more postero-laterally than the others. *p.sp.* posterior spiracle; *an.* anus.

Fig. 13. Puparium of *P. hyoscyami*—ventral view. $\times 7$.

Fig. 14. Puparium of *P. bicolor*—ventral view. $\times 8$.

Fig. 15. Buccal-pharyngeal apparatus of mature larva of *P. hyoscyami*—right lateral aspect, drawn from preparation previously treated with potash and mounted in canada balsam (camera lucida). $\times 40$. *md.s.* mandibular sclerite; *i.s.* interstitial sclerite; *h.s* hypostomal sclerite; *c.p.s.* cephalo-pharyngeal sclerite; *pf.s.* perforate sclerite; *d.p.* dorsal arm of cephalo-pharyngeal sclerite; *v.p.* ventral process of cephalo-pharyngeal sclerite; *a.* antenna.

Fig. 16. Buccal-pharyngeal apparatus of *P. bicolor* (the preparation similarly treated to the previous). $\times 18$. Lettering as in Fig. 15. *pt sp.* right prothoracic spiracle. The two subtended arms of the dorsal processes shown, one of which belongs to the left cephalo-pharyngeal sclerite.

Fig. 17. The same dissected out and more highly magnified. For significance of lettering refer to Fig. 15 (camera lucida). *d.p.* denticular process.

Fig. 18. Left wing of adult female of *P. hyoscyami.* $\times 26$. *an.* anal lobe; *al.* alula; *as.* antisquama; *aux.* auxiliary vein; 1–6 first to sixth longitudinal veins; *c.v.* costal vein; *h.v.* humeral vein; *cr.v.* anterior cross-vein; *a.cr.v.* anterior basal cross vein; *p.cr.v.* posterior basal cross vein; *c.c.* costal cell; *s.c.* subcostal cell. *m.c.* marginal cell; *sm.c.* submarginal cell; $p.c.^1$, $p.c.^2$, $p.c.^3$, first, second, and third posterior cells; *d.c.* discal cell; $b.c.^1$, $b.c.^2$, first and second basal cells; *a.c.* anal cell.

Fig. 19. Left anterior leg of adult female of same, to show arrangement of the bristles. $\times 19$. *tr.* trochanter; *f.* femur; *t.* tibia; *ta.* tarsus.

Fig. 20. Middle left leg of same. $\times 29 \cdot 5$. Lettering as in Fig. 19.

Fig. 21. Posterior left leg of same. $\times 26 \cdot 5$. Lettering as in Fig. 19.

Fig. 22. Adult female of *P. hyoscyami.* $\times 15$.

Fig. 23. Mature larva of *Opius nitidulator.* $\times 16$. Drawing made from specimen dissected out from a puparium of *P. hyoscyami.*

Figures 16, 18, 19, 20, 21 were drawn with the aid of the Zeiss-Greil drawing apparatus by means of which most exact reproductions are obtained.

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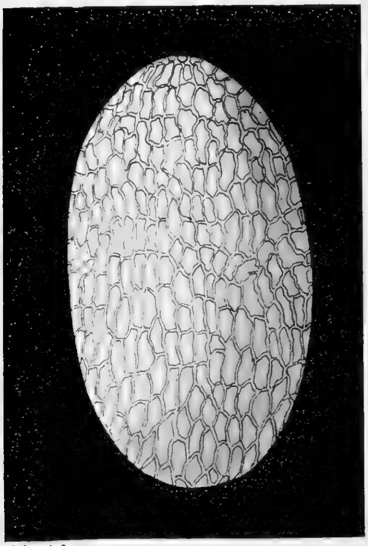

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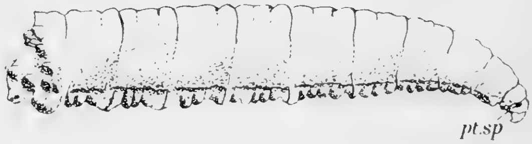

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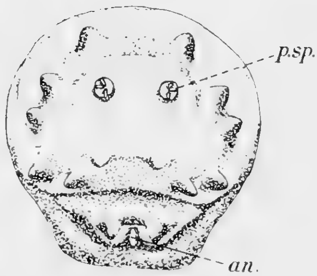

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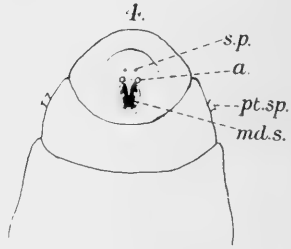

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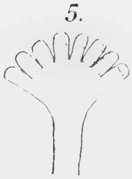

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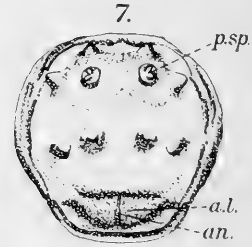

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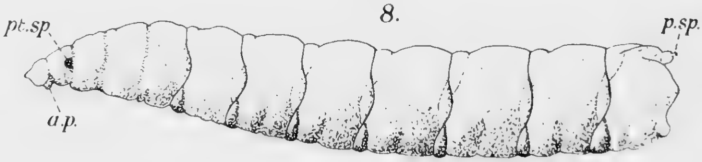

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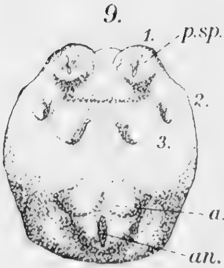

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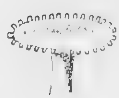

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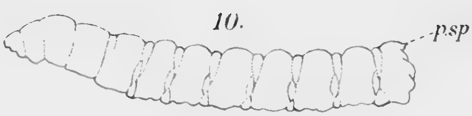

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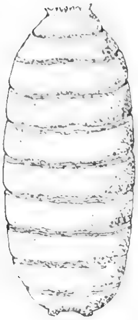

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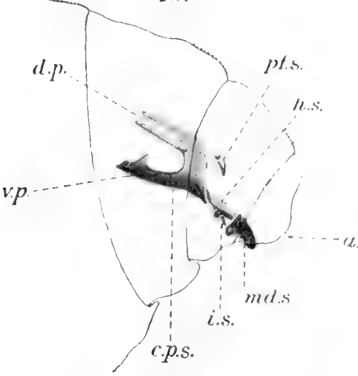

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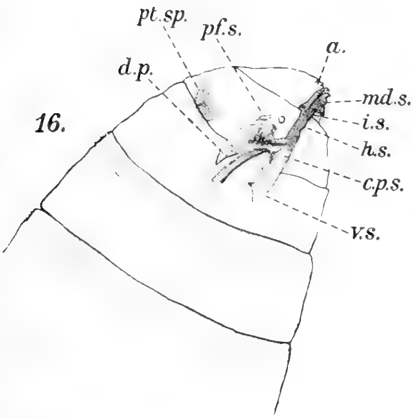

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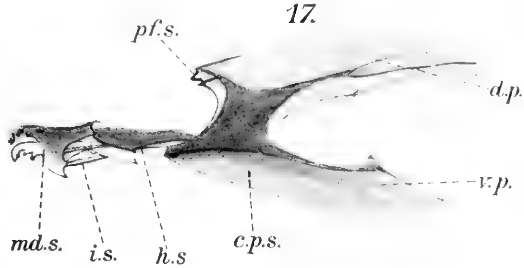

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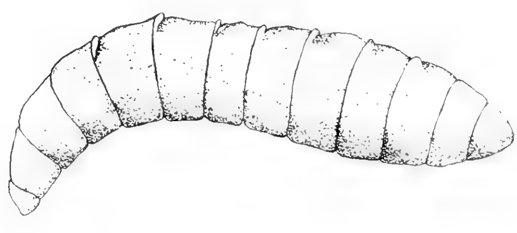

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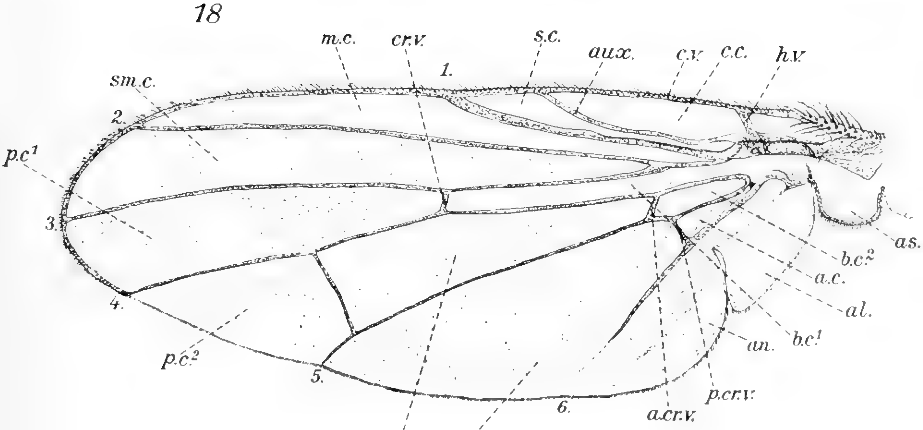

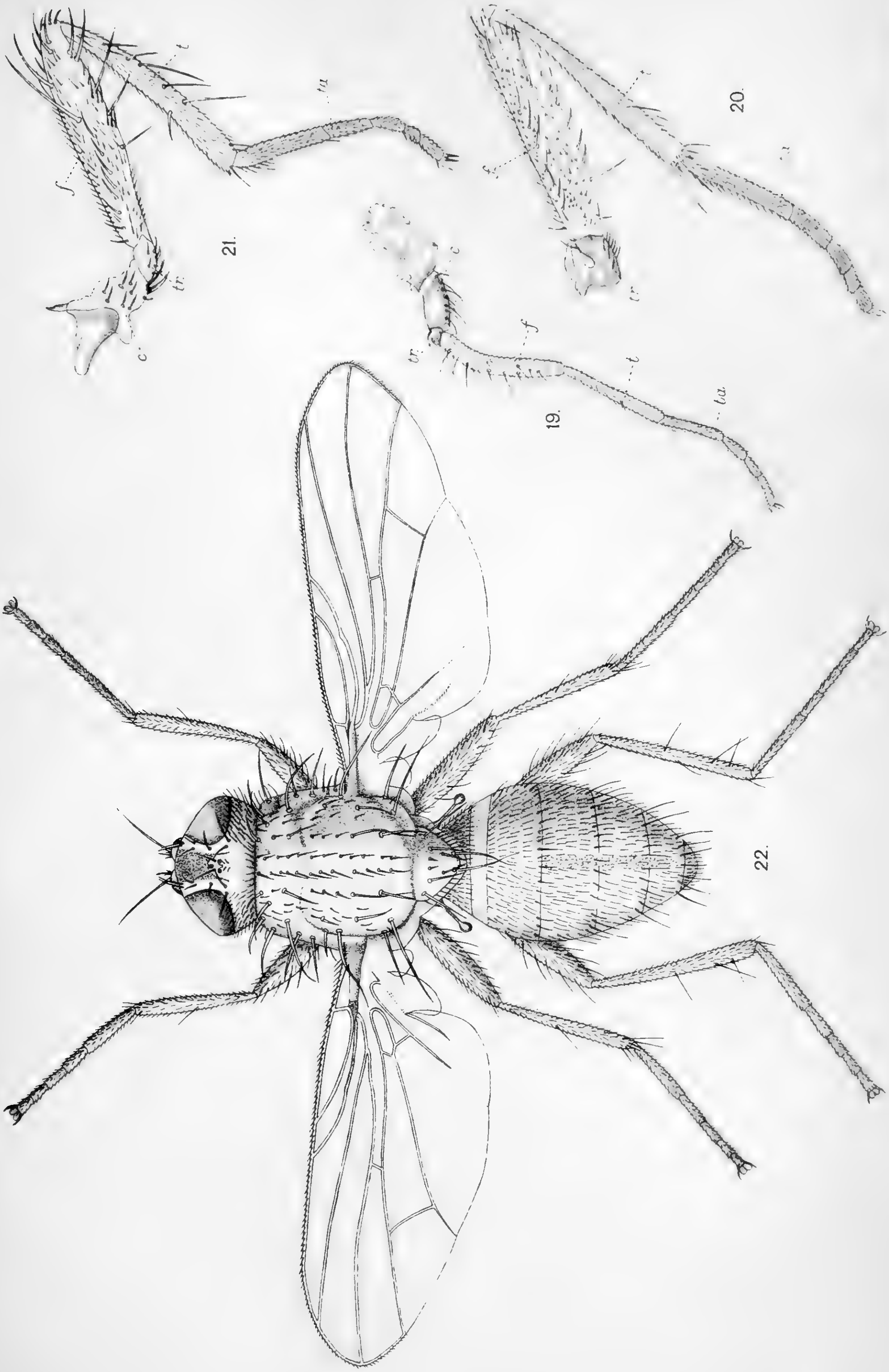

Pegomyia hyoscyami.

THE CATERPILLARS ATTACKING THE OAKS OF RICHMOND PARK, WITH AN ACCOUNT OF AN EXPERIMENTAL SPRAYING WITH LEAD CHROMATE.

By R. H. DEAKIN.

THE oak trees of Richmond Park have suffered very extensively of late years from the attacks of caterpillars.

I have not personally seen the damage done in previous years, but from all accounts the trees last year (1912), as also the year before, were almost stripped of foliage, presenting as a result the appearance of dead trees. A secondary growth of foliage then occurs. The period of maximum damage is said to have occurred in June, the time doubtless varying with the weather conditions in the spring. Impressed by the serious nature of the damage, the authorities at Kew Gardens communicated with the entomological department of the Royal College of Science, and Professor Lefroy, under whose guidance I have been working, took the matter up.

It was decided that one section of the oaks in the park should be kept under observation and sprayed and for this purpose Ham Cross Plantation, consisting of some 400 large oak trees planted in 1825, was chosen.

This plantation, presenting a very compact area of trees, has been very severely attacked in previous years.

I first visited the plantation in the third week of April. Some half dozen trees were already breaking into leaf and on these minute caterpillars were observable.

From this time onwards the number of caterpillars and the accompanying damage to the leaves increased rapidly, and it became possible to collect the different forms for the purpose of breeding out the moths.

The two commonest caterpillars were soon seen to be those of *Tortrix viridana*, the leaf-roller moth, and *Cheimatobia brumata*, the winter

moth. The caterpillars of these two forms of moth far outnumbered the rest of the species present. The leaf-roller was likewise somewhat more numerous than the winter moth.

The moths bred out were identified in the British Museum.

The following is a list of the species identified, the geometers being identified from their caterpillars.

Noctuidae.	*Calymnia trapezina* L.
Geometridae.	*Oparabia dilutata* Bkh.
	Hybernia defoliaria Cl.
	Cheimatobia brumata L.
Tineina.	
Sparganothidae.	*Batodes* (Capua) *angustiorana* Hw.
Olethreutidae.	*Spilonota ocellana* Schiff.
	Gypnosoma dealbana Fröl. (*incarnana* Hw. nec Hb.)
Tortricidae.	*Tortrix viridana* L.
	Tortrix (Pandemis) *ribeana* Hb.
	Archips (Cacoecia) *podana* Sc.
	Archips (Cacoecia) *xylosteana* L.
	Archips (Cacoecia) *lecheana* L.
Coleophoridae.	*Coleophora lutipennella* Z.

C. trapezina was not very numerous, only a few caterpillars being found. The moths hatched out at the beginning of June. These were the largest caterpillars found on the oak, but owing to their small numbers can hardly be classed as pests.

O. dilutata was also scarce. One caterpillar of this species was found parasitised, presumably by a Tachinid, the egg of the fly adhering to the dorsal surface of the caterpillar. Unfortunately the adult was not bred out.

Although nothing like so numerous as either, *Hybernia defoliaria* ranks next in importance after *C. brumata* and *T. viridana*. Being of a fair size and of an active disposition it causes considerable damage to the leaves. *C. brumata* was very numerous and a large proportion of the damage must be attributed to this caterpillar. The caterpillars of this species disappeared about the beginning of June, pupating in the ground below the trees. The use of grease bands to catch the fertilised female as she climbs the tree to lay her eggs should help to keep this pest in check.

Of the Microlepidoptera, none of the species identified are sufficiently numerous to be considered as pests with the exception of *Tortrix viridana*. *Archips lecheana* L. occurred pretty frequently and was successfully

bred out from a dark greenish-black caterpillar, yellowish-green ventrally and laterally and on the dorsal surface of the last two or three abdominal segments. Head dark brown with two black bands. Prothorax deep black. The caterpillar of *Archips podana* Sc. is almost an inch long when fully grown. The colour before the last moult is greenish-blue, with four spots of lighter colour on the tergum of each segment. Head reddish-brown.

Tortrix ribeana was bred from a caterpillar characterised by the size and prominence of the dorsal spots, these being white and the rest of the body pale green. Head with three or four longitudinal brown stripes. This moth was first hatched out on June 3rd.

Coleophora lutipennella Z., is quite common on the oak, the caterpillar living in a tube and boring under the epidermis of the leaf—this resulting in a dead brown patch on the surface. The caterpillar of another Tineid moth, *Lithocolletis* sp., was found to be very common during June, many leaves being covered with areas of dead epidermis due to the mining of the caterpillar.

Gypnósoma dealbana Fröl., I am told, has not previously been recorded from the oak.

By rolling up the leaves and eating the area so enclosed, *T. viridana* causes considerable damage. I was never successful in finding the eggs in the spring, but judging from the position of the young caterpillars on the early buds of the oak, the eggs themselves cannot be very far from these buds, if not actually on them. I believe the eggs of *T. viridana* have never been observed and described. The larvae are full grown in three to four weeks and pupate under the rolled up leaves. By the 4th of June almost all the caterpillars of *T. viridana* on isolated oaks in the park had pupated, those on the Ham Cross Plantation being slightly later. The period of pupation lasts roughly a fortnight and by the 15th of June many moths were found hidden in the lower branches of the oaks.

About this time I observed on the trees a considerable number of minute pale coloured caterpillars of the leaf-rolling type. The original brood of *T. viridana* had so far as is known all by now pupated, and the question arose, Is this a second brood of *T. viridana*. The caterpillars had the characteristic appearance of those of *T. viridana* and their occurrence when the original brood had apparently all pupated seems to support the idea of a second brood.

Moths kept in captivity were found in copulation and one female later laid eggs on the back of an oak leaf, about June 12th. The eggs

were rounded, slightly flattened and of a yellowish-brown colour. They were about ·75 mm. across and occurred singly or in twos or threes buried in scales from the abdomen of the moth and in some cases with bunches of scales sticking out like bristles.

Although unfortunately not absolutely established I think there is little doubt that a small caterpillar found eating the epidermis of the leaf some days after the eggs were laid had hatched out from one of these same eggs.

Other eggs however failed to develop, so that this question of a second brood remains somewhat doubtful as I was unfortunately obliged to give up the investigation at this critical period. Most writers say nothing of the existence of a second brood. Judeich and Nitsche in their *Lehrbuch Forstinsektenkunde* (1895) believe there is but one generation, but mention other German investigators who believe that two exist, and that the second hibernates as a pupa from which the moths appear in April, the second brood of moths in the year appearing in June and July. One of these investigators (Feussner, on *T. viridana*, *Zeitschrift für Forst u. Jagdwesen*, VI, 1874), found larvae and pupae, which he believed to be *T. viridana*, in leaves spun together, the time being the end of September. He was unsuccessful however in rearing the moth from them.

The importance of this question is obvious as it concerns not only the second brood and hence the liability of the oaks to a second attack but also the way in which the first brood makes its appearance in the spring.

Should it be found that the foliage undergoes a second attack, by leaf-rolling caterpillars, and I believe it has been observed that the attack does occur in two stages, then the problem of this second brood should be easy of solution. A large sawfly larva was found to be fairly common on the oak and under conditions favourable to its increase might develop into a pest.

Natural Checks.

Large numbers of rooks and starlings were noticed in the tops of the oaks of the plantation, doubtless feeding on the caterpillars.

The wild birds in the park have been artificially fed during the winters of 1910–11 and 1911–12. Last winter being an open one, much less feeding was done and Mr Pullman, the park superintendent, suggests that the tits and other small birds, being dependent on the natural supply

of food, may have done something to account for the comparatively small amount of damage, which this year has been done to the oaks by the caterpillars. Unless however *T. viridana* hibernates as a pupa, which might serve as food for the birds, these could do little good in the winter unless indeed they eat the eggs of *T. viridana* and *C. brumata*.

Parasites. *Oparabia* has been mentioned as being parasitised by a Tachinid fly.

No case of parasitism on the winter moth larva was observed.

Only a small percentage of leaf-roller caterpillars were parasitised.

At the beginning of June 60 pupae were collected from the trees and from these 43 moths hatched out. Twelve pupae died but were not parasitised. The remaining five were parasitised, two by an Ichneumon (*Pimpla arctica*), one by a Braconid (*Meteorus laeviventris* (Wesm.) and two by Tachinid flies one of which was hatched out and identified as *Thrytocera* (*pilipennis* Fln. ?).

This gives a percentage of about eight parasitised caterpillars The 60 pupae were not actually identified as *T. viridana*, but since all the moths which appeared were of this species there is little doubt that the parasites appeared from this species also, but this requires confirmation. A caterpillar of *T. viridana* was also found with four bright green hymenopterous larvae attached to the hinder part of the thorax.

The caterpillar's condition was quite normal, it was apparently about to pupate.

The larvae which were about one-eighth of an inch long when full grown, existed on the still living caterpillar for three days and then left it and spun rough webs on the sides of the vessel in which they were kept. They failed however to continue their development.

Artificial Methods of Control.

Two days, May 6th and 7th were spent spraying the trees of the Ham Cross Plantation, it being hoped to cover the leaves with a stomach poison whilst the caterpillars were still young. The spray used was made from a paste of the following composition:

Lead chromate	20 or 50 %
Soft soap	10–25 %
Gelatine	·6–1·5 %
Water	9·4–23·5 %

I believe this is almost the first time lead chromate has been used in this country as a stomach poison for insect pests. The supply used

was an experimental lot, and cost £5 per cwt. One pound of the paste was used to about 30 gallons of water, this giving 1 lb. of lead chromate to every 60 gallons of spray.

Messrs Merryweather of London supplied us with a 3 h.p. petrol driven pump with sufficient metal piping and flexible tubing to reach right across the plantation. Six jets were available and with the pump working at full pressure each jet was spraying about one gallon per minute. (See Plates III, IV, V.)

About twenty students and others from the college were present to do the spraying, and mix the material.

Considerable time was spent in moving the engine and laying out the mains; rain delayed matters, and only about eight hours during the two days were actually spent in spraying.

The water was supplied in water carts by the park authorities, and a second petrol pump was used to pump it into the galvanised iron tanks in which the spray was mixed. Two of these tanks were used, each holding about 30 gallons of water, and as one was being emptied the spray was made up in the second. One pound of paste was softened in a bucket with warm water from the engine and diluted down to 30 gallons. In this way the solid matter was obtained in a very fine state of suspension, forming an admirable spray to work with. No trouble was experienced due to the paste settling to the bottom of the tanks.

During the two days some 1700 gallons of spray were used, practically every tree being reached. The pressure however was quite insufficient to drive the spray to the tops of the oaks. On the second day a fire escape was provided and with its help many of the tallest trees were thoroughly sprayed all over (Plates VI, VII). The days chosen for the spraying were the only ones available, and there is little doubt that at least a week later would have been better as then the trees would have presented a much larger area of foliage. Moreover the leaves being more fully grown would not so readily have caused the breaking of the film of spray (viz. solid matter from the spray) by their expansion, as actually was the case. On the other hand the caterpillars would have been older and hardier at this later date.

The attack of caterpillar has, throughout the park generally, been very slight this year and the damage up to the end of June inconsiderable, though one or two trees were noticed which either on account of caterpillars or for some other reason never from the beginning appeared to have the normal amount of foliage and presented a very bare appearance.

Nor can it be said that the Ham Cross Plantation fared better or

worse than the rest of the oaks in the park. Had the attack been as bad as last year's, doubtless a contrast would have been apparent between those trees which were thoroughly sprayed and trees outside the plantation which were not touched. The growth of the leaves was very rapid during the favourable weather which followed the time of the spraying, and the coating of spray, observable for some days and quite unaffected by exposure and rain, finally disappeared owing to the expansion of the leaf. Rain fell while the trees were being sprayed and to some extent this must have affected the deposition of the spray. Caterpillars fed on sprayed foliage either died at once or became starved and finally perished, so that no doubt remains as to the efficacy of the poison.

The question of the falling off in the severity of the attack this year is an interesting one. The possibility of birds influencing this, has already been touched upon.

It is possible that last season the parasitic enemies of the chief caterpillar pests were very numerous, thus lessening the numbers this year. The caterpillars appeared however to be numerous enough, especially those of *T. viridana*. It may be that the dry sunny weather of May and June this year (1913) so favoured the rapid growth of the oak foliage that this easily kept ahead of the attack of the caterpillars, the growth of foliage being greatest when the caterpillars were most numerous and dangerous.

It can readily be understood that if the growth of the foliage is delayed by unfavourable weather the caterpillars will gain the upper hand and the foliage already present will disappear and the tree will assume the bare appearance typical of years of bad attack. The weather last year (1912) I believe was favourable for the trees till the beginning of June when the weather became colder and damper. If the caterpillars were still active at this time, they may have caused the stripping of the trees, on the cessation of the fine weather.

I should like to take this opportunity of thanking Professor Lefroy for the advice and assistance which he gave me during this investigation, and Mr Pullman, the park superintendent, for his advice about the trees and caterpillars.

[Mr Deakin's observations were put an end to by his appointment as assistant to the Government entomologist, British East Africa. The almost entire absence of any visible effects of caterpillar attack anywhere in Richmond Park in 1913 destroyed the value of our experiment as no plantation in the park was affected. But it showed that

trees could be sprayed in England as elsewhere, and that the cost was not excessive. For approximately 400 trees, 1700 gallons were used or 56 lbs. of lead chromate paste.

Our thanks are due to Messrs Merryweather who provided the machinery and ladders; their apparatus worked admirably, even though we had hundreds of yards of main, branch and rubber pipes out at a time: the whole work was done by students except the actual control of the petrol-driven motor. The illustrations attached speak for themselves.

To the courtesy of the Office of Works, we owe the opportunity to make this experiment; it is unfortunate that no result was obtained. H. M. Lefroy.]

A BACTERIAL DISEASE OF FRUIT BLOSSOM.

By B. T. P. BARKER, M.A. and OTTO GROVE.

(*University of Bristol: Agricultural and Horticultural Research Station.*)

In the *Gardeners' Chronicle* of May last year an announcement was made by one of us that several cases of blackening of pear blossoms, commonly supposed to be due to frosts or cold winds, had been traced to the action of a bacterium. For several seasons past the blackening of the blossom followed by the death of the flower has been observed in the plantations of this institution at Long Ashton, the severity of the attack varying from year to year, but on the whole showing a tendency to increase. In the spring of 1913 the disease was much more marked than at any time previously; and although the trees of most of the varieties grown there were heavily laden with blossom, the crop was a failure, certain varieties being especially severely attacked and failing to produce more than half a dozen or so mature fruits per tree on good sized trees ten or twelve years old. Until then no particular attention had been given to the disease, the damage being attributed to the action of frost and cold winds according to the generally accepted view. Mr J. W. Eves, at that time pomologist at this station, observed during the course of pollination work on pears early last April that in many instances the pistils of unopened flowers were already badly discoloured, and was impressed with the general resemblance of the features of the disease to an attack by a parasitic organism rather than to damage caused by unfavourable weather conditions. He accordingly submitted to us typical diseased blossoms for examination, selecting cases where frost could not possibly be held responsible for the damage. In the case of the first flower examined a large semi-transparent gelatinous-looking colony of bacteria was readily seen under the low power of the microscope situated on the surface of the discoloured disc of the flower. From this colony streak and plate cultures on beerwort gelatine were at once made, and in these in the course of two or three days abundant growth was obtained. The cultures in all cases proved to be pure, only

one type of organism, a rod-like bacillus, developing. After the necessary trials to test purity, stock cultures were made, and material from these was taken for use in infection experiments. The latter gave positive results quickly and without any difficulty, the characteristic discolouration of the flowers following a few days after infection.

It was thus soon demonstrated that the disease was bacterial in nature; and a detailed study of it was begun. Our work is still incomplete, the limited duration of the flowering season curtailing infection experiments and other observations on the flowers themselves in a living condition; but it has been thought desirable to publish a preliminary account of the disease rather than to defer it until the results of the current season's work are available. The present paper is concerned primarily with the general characters of this disease, which, so far as we are aware, has not hitherto been recorded, and a description of the causal organism.

The Characters of the Disease.

The nature of attack and the result vary considerably in individual flowers; but the two following forms are perhaps the commonest.

In the one case the sepals are the first parts of the flower to show signs of attack. Their tips turn grey and then begin to blacken. When weather conditions favour the disease this blackening soon spreads to the whole of the calyx and in due course down to and along the flower stalk. The infection of the latter quickly leads to the death of the whole flower bud. This mode of attack is common with young, unopened flower buds. The flower bud blackens and shrivels up. In moist weather it soon falls from the blossom truss; but under drier conditions it withers and dries up, remaining attached to the flowering shoot or spur for weeks or even months. It is not uncommon to find in late summer whole trusses of these blackened mummified blossoms still on the spur. In cases where the whole of the blossoms of a truss are affected, the consequences as regards the future history and fruiting capacity of the spur bearing the truss are serious. The whole truss of blossom eventually dies and falls off, leaving the spur as a bare stump devoid of foliage. This stump may eventually die back entirely to the point of its attachment to the branch carrying it; and in such cases, if numerous, the future fruiting capacity of the tree is seriously restricted for several seasons at least, until new growth and fresh fruit spurs have had time to develop, on account of the large stretches of barren

branches thus created. In less severe cases the apical portion of the spur is alone affected, dormant buds in due course breaking to form fresh growths ; but even in such instances some time must elapse before the spur is once more properly furnished with fruit buds. The variety Catillac seems particularly susceptible to the disease in this form ; and trees of this sort at Long Ashton are laden with spurs showing this type of damage in all degrees.

In the other case the first signs of trouble appear in the receptacle of fully opened flowers as minute greyish-black spots. These rapidly increase in size until they finally coalesce. In a short time the entire receptacle is blackened and the disease spreads to the ovary. As a consequence the fruit fails to set properly and sooner or later drops from the spur as in the type of attack previously described. The main difference between these two forms of attack is that in the case first described the initial points of infection occur in the external whorls of the flower, the disease catching the eye therefore at a very early stage, whereas in the second instance the attack begins on an internal structure of the flower and may escape observation entirely, the failure of the fruit to set properly being attributed wrongly to imperfect fertilisation.

In both cases the description given applies to examples in which the disease spreads comparatively rapidly through the floral structures ; but under some conditions the extension of the disease proceeds more slowly. Before it has made serious headway the fruit may have set and even have swelled to the size of a pea or larger before the injurious effect puts a stop to further development. Sooner or later, however, the death of the young fruit generally results, although in a few cases signs of attack have been noticed on quite large fruits ; and it is possible that at times an affected fruit may actually reach maturity without serious damage. Such cases are probably infrequent if the disease once establishes a footing. The rapidity of the spread of the disease in an infected flower appears to vary considerably, depending largely upon climatic conditions. Cold, wet weather seems to favour its development and, conversely, warm dry weather restricts it. Further reference to the influence of various conditions will be made later.

In addition to these two typical forms of attack a variety of other types has been observed. In some cases the stigma is first affected, becoming unhealthy and discoloured in appearance. The blackening extends thence downwards through the style to the ovary, the whole pistil eventually turning completely black and failing to develop into a fruit. In other cases small blackened areas appear first on one or more

of the petals. The remaining parts of the flower may or may not be attacked in due course. In the latter event the affected petals fall as the flower ages, and the young fruit may then develop normally.

While attacked flowers at times remain attached to the fruit spur for a comparatively long period, even when the disease has obtained a strong hold, it is very common to find flowers which fall at the slightest touch, although the external signs of disease are limited to a few small black spots on the receptacle. A slight shaking of the tree suffices to cause blossoms in all stages of development to fall in showers. Young fruits which appear to have just set are particularly liable to come off in this manner. Examination of the internal parts of the flower in such cases generally shows that the ovary is more or less completely blackened.

The disease spreads very rapidly from flower to flower; and, if it makes its appearance when the tree is just beginning to blossom, it may spread to nearly all the flowers on the tree during the three to four weeks over which the latter is carrying open blossom.

While the disease in its most serious form is concerned mainly with the flowers, other parts of the tree are attacked. The young leaves which appear during the blossoming season frequently show small black spots or areas, very similar in general character to the blackened spots which occur at the points of infection on the petals. Serious damage to the foliage does not generally result, the spots remaining small and eventually drying up and falling out. The leaves developing around the blossom trusses on the fruit spurs are usually most severely attacked. The disease on the foliage generally starts at the tip of the leaf, but occasionally at some point along the margin.

The fruit spurs of the tree are also often attacked; and it is possible that this feature of the disease may prove to be the most serious. Reference has already been made in passing to the fruit spur attacks when describing the course of the disease of the blossom trusses: and it has been shown that after the death and fall of the flowers of the truss the spur is left as a barren stump, which sometimes dies back as far as the point of its attachment to the branch carrying it, but occasionally survives and produces lateral growths which develop in due course into either shoots or branch spurs. In both cases the tissues of the spur are attacked by the bacillus. When death of the spur results, apart from the loss of the spur by the tree no evil effects may follow; but if the spur survives, the infected tissues harbour the organism throughout the summer and winter and may prove to be responsible for an outbreak

of the disease the following spring through the lateral buds which were formed after the original attack. On cutting transverse sections through such a spur just below the point of attachment of the diseased flower truss a number of small brown spots are seen, both inside and outside the cambium. In longitudinal section these appear as brown lines, which at times extend back ½–1 inch or more into the woody portion of the spur. The bacillus is present in these affected portions; and proof is now forthcoming that it remains in a living condition there over the winter. It seems likely, therefore, that new growths from such spurs are also infected. The affected portions of the tissues of the spurs do not increase in size to any considerable extent; and no serious damage to the surrounding tissues results immediately, except in the severe cases where the whole body of the spur dies back. Possibly in the latter event the death of the spur may be due not so much to the organism in question as to fungi, such as *Nectria ditissima* or *Sclerotinia fructigena* which have the opportunity of infecting the spur at the point of severance of the blossom truss. At present no decisive evidence either way has been obtained; but, as will be seen later, infection experiments with the bacillus on woody branches have shown little serious damage, and the balance of probability therefore points to the action of other organisms in cases where the spur dies back.

In the foregoing description of the disease reference has been confined to its characters on the pear as host. There is reason to believe, however, that a number of other plants are also susceptible to attack. A bacteriological examination of discoloured parts of flowers of apples, cherries, gooseberries, and plums has been made, and in many cases there has been found in the diseased areas a bacillus in practically a pure state, which on isolation has proved to be the same organism as that occurring on the diseased pear flowers. It has also been found on the tissues of the flowers and leaves of various other plants in parts showing discolouration. Since at present, owing to our attention having been given mainly to the disease on the pear, very few infection experiments have yet been made on the other plants mentioned, the evidence connecting the bacillus with the disease in the latter cases is not absolutely conclusive; and pending further investigation it is not proposed here to do more than call attention to the fact of the occurrence of the organism in association with affected parts on other kinds of plants.

There appears to be a marked difference in the susceptibility of different varieties of pears to attack. The organism has been isolated from diseased flowers of practically all the varieties grown in the plantations

at this institution, including the following kinds: Beurré d'Amanlis, Catillac, Vicar of Winkfield, Louise Bonne de Jersey, Conference, Bellissime d'Hiver, Dr Jules Guyot, Williams' Bon Chrétien, and Pitmaston Duchess. Of these sorts the two first named are much more badly attacked than the remainder; and most of the trees of those kinds, although covered with blossom, produced very few fruits in 1913, some indeed failing to yield a single pear. After examination of the older fruit spurs of the trees of all of the varieties named, it is evident that also in years prior to 1913 the two varieties in question have suffered more severely than the other kinds.

In the case of apples discoloured flowers of Beauty of Bath, Bramley's Seedling, Allington Pippin, Devonshire Quarrenden, and Duchess of Oldenburgh have been examined, and from each sort the bacillus has been isolated. There is not sufficient information available yet to show if some varieties are more susceptible than others. Few kinds of plums have yet been examined; but cultures of the bacillus have been obtained from the Victoria variety and the Myrobella plum. Only two cases of cherry blossom have been examined, viz. the Norwegian cherry and a kind sent through the Board of Agriculture without name. In both instances the organism was isolated.

There is little doubt from the specimens of fruit blossoms examined last year that the disease is very widely spread. Not only was it repeatedly found in the immediate neighbourhood of Bristol, but also in many other parts of the country. The bacillus has already been isolated from affected pear flowers sent to us from Devon, Teddington, Wolverhampton, Stroud, Ross, and Offenham; and from apple blossom sent from Berkeley, Ledbury, Elsenham, Essex, and Hailsham. The occurrence of the organism over so wide an area suggests the probability of a general distribution throughout the midland and southern counties at least; and the fact that it has been isolated from a number of plants other than pears and apples, in which blossom or foliage damage was slight, raises the question of its pathogenic character in all cases.

It undoubtedly is responsible for the disease of pear blossom in the forms already described, since branches of pear trees carrying unopened and undamaged blossom have been brought on under greenhouse conditions and have in due course borne flowers which have developed the disease both after artificial inoculation with the bacillus and in many cases without deliberate infection. Also abnormally late blossoms produced in the open in June have been found to be affected. In such instances the possibility of frost damage has been excluded, care having

been taken to ascertain that the flowers showed no sign of such damage before being selected for the experiments under cover. On the other hand many cases occur under outdoor conditions in which it is difficult to decide whether the damaged blossom has been affected by the organism or by frost, the type of damage appearing to the naked eye very similar in either case. Again in other instances there is no question of the damage being due to frost. In this connection it may be noted that the blackening or browning of the pistils in unopened or partially opened buds can be caused by frost even when the other parts of the flower are quite unaffected. Striking cases of this kind have been observed this spring on the Myrobella plum. The bacillus having been isolated from frosted blossoms, from flowers with blackened pistils which may or may not have been caused by frost, and from undamaged fully expanded flowers of the Myrobella, it is evident that for this plant at least the organism is not always pathogenic. At the same time the tissues of the discoloured pistils have been swarming with cells of the bacillus in some instances. Further investigation is necessary before such points can be satisfactorily cleared up.

When the disease was at its height last year in the fruit plantations at this institution one of its most striking features was the rapidity with which it spread from flower to flower. Definite proof was forthcoming that this was due mainly, if not entirely, to the agency of bees and other insect visitors to the flowers. A number of bees were caught in sterilised test-tubes, while they were actually working among trusses of pear blossom. They were transferred to Petri dishes containing a layer of sterile malt extract gelatine, and were allowed to walk over the surface of the latter. In fifty per cent. of the cases examined it was found that colonies of the bacterium with the typical characters to be described later developed in the footprints of the bees after an interval of three or four days. The course of the bees across the plate was most strikingly mapped out by the line of colonies. It is interesting to note that perfectly pure cultures were obtained in some cases in this way, no other organism developing on the plates.

There is no doubt therefore that the dissemination of the disease is largely due to insect visitors to the flowers. Infection is carried by them from diseased to healthy blossoms, which become inoculated either through the stigmas or the points of the viscid receptacle with which the feet of the insects come into contact. It will be seen later that infection can take place by merely superficial inoculation with the organism in this manner.

Probably the start of an outbreak at the beginning of the flowering season occurs in two ways. In the first place it seems likely that in cases where blossom is produced on a spur the tissues of which are already infected with the organism, some of these blossoms are infected at the time of their formation through the spur tissues. In the second place, since the organism has been found in the soil of fruit plantations, it is likely that insects or wind convey infection from that quarter in many cases.

In the light of present knowledge the organism seems to be a form of very wide, if not general, distribution in this country, occurring at times in the soil of fruit plantations and possibly having a natural habitat in the soil. It is frequently found in flowers, especially such as rosaceous species, where a prominent nectar-secreting disc, on which it appears to thrive, is present; becoming parasitic in some cases, notably the pear, perhaps being aided in obtaining entry to the tissues through frost or other damage. It is carried from flower to flower by bees; and finally, in the case of the pear at least, is capable of gaining access to the tissues of the fruit spurs and remaining in an active state there throughout the year.

Infection Experiments.

These experiments have been mainly carried out on pear blossom, flowers of the varieties Catillac, Beurré d'Amanlis, Louise Bonne de Jersey, and Vicar of Winkfield being for the most part used. The number of flowers infected was very large, and the infection was in nearly all cases successful.

The usual procedure in these experiments was to select young healthy shoots bearing blossom in an unopened or comparatively unopened condition, any individual flowers showing traces of natural infection being removed. After infection the shoots were kept in the laboratory or greenhouse at ordinary temperature in covered glass vessels, the atmosphere of which was kept moist by the water in which the cut ends of the shoots were placed. The mode of infection varied. In some cases drops of water containing the bacteria were simply placed upon various parts of the flower by means of a sterilised platinum loop, care being taken to avoid injury to the tissues of the flower. In other cases the culture was applied with a fine needle, the tissues being slightly pricked. It may be added that in all infection experiments pure cultures of the organism were alone used, the usual precautions against foreign infection being taken by the use of sterilised instruments and other necessary

details. It was found that although infection was obtained by both methods, the disease set in much more readily when the tissues were punctured. By the latter method the flowers formed small moist drops in three to four days after infection at most of the injured spots, and on the fifth day distinctly grey coloured slimy colonies could be seen. After six to seven days the affected areas were black and exactly like the natural ones. Microscopical examination of the tissues of these regions showed a heavy growth of the organism, and the latter after isolation in pure culture again presented all the characters of the original type. It is noteworthy that in practically every case tested the bacillus in question was the only one isolated from the affected tissues. In due course the blackening spread to other parts of the flower in the manner already described in connection with the disease under natural conditions. Control experiments in which the flowers were punctured with a sterile needle, but not inoculated with the organism, gave in the large majority of cases negative results. Some discolouration occurred at the point of injury, but nothing further resulted. Where the control experiments in a few cases showed a development of the disease at such points, it is probable that the organism was already present on the flower at the time of injury. There is evidence to show that the bacillus is at times present on the surface of perfectly healthy flowers.

The infection experiments in which the tissues of the flowers were uninjured yielded less striking results, although in the great majority of cases the disease eventually developed.

Owing to the extent of the disease on the trees at Long Ashton last spring, the selection of unaffected blossom trusses for infection experiments was difficult. Many instances of the disease developing without artificial infection on selected trusses apparently quite healthy occurred ; and although there is no question of the success of the infection experiments, there were occasions when it was difficult to decide as to natural infection also playing a part.

Infection experiments were also made on flowers on trees growing in the open plantations at this institution. These were less satisfactory than those already recorded. In the first place it was almost impossible to distinguish between the results of artificial and natural infection, the latter being so common, when the infected trusses were not enclosed in paper bags ; and secondly, when paper bags were used, a large number of artificially infected trusses remained healthy, the controls behaving similarly. Probably this was due to the effect of bagging on the flowers. While at present we know little as to the influence of external conditions

on the disease, the available evidence indicates that the disease is encouraged by a comparatively low temperature and a damp atmosphere and conversely is checked by hot and dry weather. The conditions within the bags approximate to the latter type.

Since it was discovered that the tissues of the fruit spurs of pears were frequently attacked by the organism several infections were made in young shoots of apples, pears, plums, and gooseberries, by means of needle punctures. Control punctures with a similar sterile needle were made at the same time. The two sets of shoots were compared at monthly intervals, and it was found that, although the inoculated punctures were full of the living bacteria, so much as to show that some multiplication had taken place, the organisms had not spread appreciably in the tissues nor caused more than a minimal amount of local damage. Macroscopically the infected shoots differed in no way from the controls.

A few infections on Catillac pear fruits when they had nearly attained their maximum size were also made by puncture. No serious results ensued.

Isolation, Description, and Cultural Characters of the Bacillus.

As already mentioned, microscopical examination of the tissues of the discoloured areas of the flowers, leaves, and fruit spurs showed them to be swarming with cells of a rod-like bacterium. The detection of the organism was generally difficult and frequently impossible when material for examination was selected from the centre of the blackened patches owing to the alterations in the diseased cells of the tissues. The formation of granular substances and the abundance of comparatively opaque and darkened cell contents prevented satisfactory identification of the presence of the parasite. It is indeed probable that the latter dies off in those places. When, however, portions of the tissues at the periphery of the discoloured spots bordering on healthy unattacked cells were examined, there was generally no difficulty in finding the bacteria in abundance and in a most active condition. There appears to be a zone of the bacteria along the periphery of the affected areas, where fresh cells are being attacked, which advances with the spread of the discolouration ; while behind, where the cells of the host have been killed, the parasite has migrated or died off.

The isolation of the organism from the peripheral portions of affected areas was simple. Plate cultures of malt extract gelatine infected from such regions gave colonies of the bacterium in the course of four or five days. Many independent series of plate cultures have been made from

different flowers, leaves, and fruit spurs, and in the great majority of cases the characteristic colonies of the organism have developed. It was rarely that other organisms appeared on the plate cultures; and in such cases the foreign form was nearly always *Monilia fructigena*, the "brown rot" fungus. It is not uncommon to find flowers attacked at the same time both by this fungus and the bacillus.

The isolation of the bacterium was especially easily effected from flowers showing newly developed small, black spots on the receptacle. By touching these spots with the point of a sterilised needle, and making streaks with the latter over the surface of a sterile plate of the nutrient gelatine, pure cultures were very often immediately obtained. From older, dried up material, the growth is not so quickly developed.

Pure stock cultures of the organism were kept on various nutrient substrata and in liquid nutrients. In most cases the organism retained its vitality for several weeks at least and did not lose its parasitic powers, infections on fresh flowers and leaves giving positive results. In due course, however, on most of the media tested it eventually died off; but cultures on potato blocks have retained their vitality and parasitic abilities for over eight months.

The bacillus is a rod $2\text{–}4\,\mu \times \cdot 5\text{–}\cdot 8\,\mu$ in dimension. Although satisfactory stained preparations of the flagellae have only been obtained in one or two instances after repeated trials, there seems no doubt that the cells are lophotrichic. The flagellae, two or more in number, are at least four to five times as long as the cells themselves. The organism stains well with the usual stains, and especially so with gentian violet. It is also stained by Gram's method.

It grows well in malt extract solution (sp. gr. 1·040), glucose-peptone water (5 % glucose, 1 % peptone), and in neutral and slightly acid (+ 0·15 % normal) bouillon.

The bacillus is highly motile in young cultures, showing quick progressive movements. The motility depends greatly upon aeration. This is very well shown in ordinary coverslip preparations made from colonies or young plate cultures, the bacillus coming to rest in about two minutes at the centre of the slide, the movement being progressively more active in the cells passing outwards towards the edges of the slip. At the latter region or in the neighbourhood of air bubbles movements continue for about 20 minutes. It then ceases and agglutination takes place. After all have come to rest, if the slip is lifted for a few moments and then replaced, nearly all the cells are found in an active state of movement.

The cells are mostly single or in pairs, seldom in long chains. No endospores have been observed in any cultures. Involution forms are produced very readily, especially at temperatures of 25–30° C., and in old cultures. These involution forms attain often a length of about 100 μ and are irregularly swollen. The optimum temperature for growth is about 18° C.

In bouillon at 15–18° C. a slight cloudiness is formed in 24 hours, and a good growth obtained after two days; after four days there is an appreciable deposit and a slight thin film on the surface of the liquid. At 25° C. growth is a little slower, and at this temperature after 48 hours the cells gradually increase in size and begin to lose their motility. Small chains and involution forms are then soon developed, and after four to six days the organism has completely changed its original form. It grows out into long threads and large, irregularly swollen and often very granulated forms. Movement is then practically stopped.

At a temperature of 18° C. the cells do not change their form or lose their motility until the cultures are getting old.

If involution forms from a six-day old culture are placed in fresh bouillon and kept at a lower temperature, the new cells quickly begin to assume the normal size and motility.

In two months old bouillon cultures, the cells collect at the bottom of the vessel, forming a disc of somewhat gelatinous character, and the liquid is left perfectly clear.

With bouillon gelatine stab cultures show feeble development after 24 hours. After 48 hours there is good growth with crateriform liquefaction; after six days the liquefaction is stratiform, and after eight days all the gelatine is liquefied and a flocculent deposit formed. Streak cultures after 48 hours show strong liquefaction, there being a broad concavity in the gelatine and a cloudy liquid and white, flocculent deposit in the tube.

In plate cultures of gelatine media colonies are extremely characteristic after four days. The submerged colonies are small and white, the surface colonies are liquid with smooth edges, round, 6–8 mm. in diameter, concave, moist and glistening, semi-transparent, often with small white nuclei in the centre and concentric rings of granular matter beyond, and with whitish margins. Under the microscope the surface colonies show a flocculent deposit and a margin forming a double ring.

The liquefying action is very pronounced; and in a plate culture the whole gelatine is generally liquefied in about eight days, even if

the plate originally contained only 8–10 colonies. A plate culture in the liquid state has a pronounced smell of ammonia.

In bouillon agar at 18° C. stab cultures give feeble growth in three days, spreading out on the surface. Streak cultures form in three days a flat, glistening, smooth-edged, whitish, spreading growth. In plate cultures the colonies are visible after 48 hours. The surface colonies after three days are small, round, raised, glistening and whitish, later spreading out over the surface. Submerged colonies are white and remain very small.

On potato a raised, yellowish-white, broad, smooth-edged growth is formed after eight days at 18° C. On parsnip and carrot a feeble growth is observed after five days. On turnip no development takes place.

In sterilised milk a good growth is obtained. No curdling takes place in eight days at 18° C., but the milk is eventually very slowly peptonised.

No fermentation takes place in 2 % solutions of saccharose, maltose, glucose, laevulose, or lactose, to which 1 % peptone was also added.

Old cultures in glucose-peptone solution exhibit a pronounced greenish fluorescence. This has not been observed in the case of any other media.

There is no indol reaction given in eight-day old cultures.

From these characters it appears that the organism is a species of Pseudomonas. So far it has not been identified with any hitherto described form; but on account of its wide distribution and occurrence in the soil it is possible that it may be known to soil bacteriologists as one of the ammonia-forming types.

ON THE PREPARATION OF COCCIDAE FOR MICROSCOPICAL STUDY.

By E. E. GREEN.

1. *Introductory Notes.*

Having been asked by several correspondents to describe the best method of preparing *Coccidae* for critical study, I have thought it might be useful to publish an account of the technique that I have adopted in my own work. I do not set it up as being the best method, as I have not experimented to any extent in other directions ; but I have gradually arrived at a procedure that appears to produce satisfactory results which compare favourably with examples of mounting that I have received from other working entomologists. I am, however, confident that useful modifications and improvements could be effected by anyone conversant with the processes employed in modern laboratories. I must also confess that I work largely by rule of thumb and have not reduced my processes to exact measures of time and quantities. I find, indeed, that the essence of success depends upon minute variations in the treatment employed—to be learned by actual experience alone.

2. *Appliances and Reagents.*

I will first give a detailed list of the appliances and reagents that I have found necessary or convenient :

Any good compound microscope, with modern objectives.
A dissecting microscope (preferably an erecting binocular).
An Abbe-Zeiss camera lucida.
A reliable stage micrometer.
Fine-pointed forceps.
Small scalpels.
Dissecting scissors.
Two or three fine camel-hair brushes.

Some "snipe-points" (the terminal feather of a snipe's wing) mounted in small porcupine quills.

Setting needles. These should be the smallest and finest obtainable.

A small (narrow) section lifter. A piece of stout silver wire, hammered flat at one end and turned up at a slight angle, serves the purpose admirably.

Evaporating dishes ($2\frac{1}{2}$ in. diam.).

Several flat-bottomed watch glasses.

Short test-tubes (1 in. diam.).

Excavated glass blocks. These may take the place of the watch glasses, as they are most useful for the reception of such reagents as oil of cloves, distilled water and various strengths of alcohol, in which the objects have to be steeped for various periods. They will stand steady on the stage of the dissecting microscope.

Glass pipettes with rubber teats.

A small glass table, with a mirror below, is of great convenience when transferring objects from one medium to another.

The following reagents will be required:

A strong solution of potassium hydrate (liquor potassae).

Alcohol, 70 %, 90 %, and absolute.

Fuchsin (acid), strong aqueous solution.

Picric acid, saturated solution in alcohol.

Glycerin, dilute.

Oil of cloves.

Canada balsam, dissolved in xylol.

Distilled water.

3. *Preparation and Mounting of Specimens.*

Coccidae do not necessarily require any prolonged process of preliminary preparation. They may be treated in the fresh condition without any difficulty. On the other hand, material that has been kept in alcohol or other liquid preservatives, or that has remained dry for many years, will respond to treatment with complete success—provided that it has not been allowed to become mite-eaten or infested with fungus.

Naked species, such as *Lecanium*, are the simplest subjects and may be best utilised to illustrate the process. The general procedure is the same for all *Coccidae*; but slight modifications (to be noticed later) will be necessary in particular cases.

Let us suppose that we have some dried leaves or twigs infested with a species of *Lecanium*. Detach a few of the insects by means of a needle or fine scalpel, taking care not to injure the margin in so doing. Select examples of different stages of growth, and take more than will be actually necessary for the final mount. Some of them are sure to be imperfect and may be discarded during the later stages of the preparation. Place the selected specimens in a small evaporating dish, together with a tiny fragment of pumice stone (to prevent too violent ebullition). Add about two teaspoonfuls of strong potash solution and heat over a spirit lamp for from two to five minutes, agitating the vessel slightly and regulating its distance from the flame so as to keep the liquid simmering rather than actively boiling. If it is necessary to prepare several different species at the same time, specimens of each may be isolated in small test-tubes (with the requisite amount of potash), plugged with cotton wool and placed erect in a small saucepan containing water, the whole being boiled together. The specimens must be examined at intervals and removed so soon as they begin to show signs of clearing. The right moment can only be learned by experience. If not treated long enough, there will be subsequent difficulty in removing the contents of the body. If treated for too long a time, the cuticle will become too tender and will tear or break up during subsequent manipulation.

During this process, note any colour given off by the objects. Certain species colour the liquid pink—or even crimson; others give off a greenish, brownish, or inky stain. A knowledge of such characteristics may be of assistance in differentiating between closely allied species.

Remove the prepared specimens, by means of the section lifter, to distilled water. Here, by a process of osmosis, further clearing will take place and part of the contents of the body will pass out into the water. I find it convenient to leave the objects in this medium for 24 hours, and I use the excavated glass blocks for their reception.

At this and all subsequent stages care must be taken to label the specimens in such a manner that they may be identified with the material from which they have been taken. This label should be transferred from vessel to vessel at each subsequent transference of the specimens. Failure to observe this precaution may lead to most unfortunate mistakes.

Before further treatment, note the form of the insect which will often have become distended to its fullest extent, when it may show characters that will be lost under subsequent compression. For instance, the lateral tentacular processes characteristic of the living

Diaspis boisduvallii usually disappear entirely when mounted in balsam. The peculiar form of the *Tachardia* insect is best shown (and figured) at this stage.

It should also be noted whether the bodies contain well developed ova or embryos. The presence of such will settle conclusively the stage of the insect, in doubtful cases.

On the following day the specimens should be transferred to clean water, when the remaining contents of the body may be easily removed by manipulation with fine needles, assisted by the mounted snipe feathers. If the body is not already ruptured, a small opening should be made at one point, through which the liquid contents may be gently worked out. Small aggregations of wax, fatty globules, or partially solid matter may be removed by inserting a fine point through the artificial aperture.

The specimens are next transferred to and washed in 70 % alcohol for a few minutes. They are now mounted temporarily on a glass slide in a drop of dilute glycerine, under a glass cover slip, for preliminary examination. After which, a few drops of fuchsin solution are run in with a pipette, and the slide is put by for another 24 hours.

Then add a few drops of picric acid solution and leave for five or ten minutes, to fix the stain.

Remove the cover glass ; flood the slide with alcohol, to redissolve the partially crystallised picric acid, and transfer the objects to a bath of 70 % alcohol, where the glycerine and superfluous stain can be washed out, together with any small fragments of the body contents that may have been overlooked during the earlier process. Such omissions can now be readily detected, as they will have absorbed a deeper stain.

When the removal of the stain has proceeded to the right point, the objects may be washed in absolute alcohol, preparatory to their removal to a bath of oil of cloves, though I have not found any ill effect following upon their direct transference from 70 % alcohol. They may be allowed to remain in the oil for about 10 minutes, after which they are finally mounted in canada balsam.

If the same receptacles and media are used on subsequent occasion great care must be taken that every specimen has been removed. Confusion and erroneous determinations have occasionally arisen through the accidental inclusion in the finished mount of one or more specimens inadvertently left over from a previous operation.

After arranging the objects neatly in the centre of the slide, I place a sufficiency of balsam on the underside of the cover glass and lower it gently on to the specimens. I used, at first, to find that the balsam,

when spreading itself under the cover glass, would disarrange my neatly disposed specimens, and even carry some of them away to the extreme margins. I now prevent this inconvenience by pressing the objects on to the glass with a small piece of thin smooth blotting paper. This absorbs the remaining oil of cloves and makes the objects adhere closely to the glass. Before adding the balsam and cover glass, the mount should be examined for the removal of any small fibres that may have detached themselves from the absorbent paper. Several specimens should be mounted on one slide, some showing the dorsal and others the ventral surface uppermost.

When dealing with strongly convex species, it is often advisable to slit the dorsum, as otherwise it will not lie flat on the slide. In such cases the venter should be separated from the dorsum and disposed so that the two surfaces can be examined side by side.

Species that are densely coated with wax, such as *Ceroplastes*, should have the waxy covering removed before the insect is boiled in potash. This can usually be done with a fine scalpel, without injuring the insect; or the wax may be dissolved in carbon bisulphide. Boiling in oil of cloves will have the same result.

The larger species of *Monophlebus* and allied genera are often so dense that satisfactory mounts cannot be made of the complete insect. It is better to divide them horizontally, separating the venter from the dorsum completely. If the insects have been preserved in alcohol, this section can be effected before boiling in potash. But, with dried examples, it is necessary to boil them for a short time, until the skin is softened, before attempting the operation. The object is then replaced in the potash and boiled until the two halves come apart and the soft inner tissues separate from the derm, leaving the latter quite clean.

The species of *Tachardia* (lac insects) are embedded in dense resinous gum which may be softened or completely dissolved by immersion in strong alcohol, before treatment.

Coccidae of the family *Diaspidinae* are concealed beneath composite scales consisting of the larval exuviae supplemented by secretionary matter. To obtain the insect itself, the scale must be lifted or turned over when the creature will be found either free or lying in the hollow of the overturned scale. If there is any difficulty in extracting the insect, the whole scale may be boiled in potash, when the secretionary matter is decomposed and the insect and pellicles freed. Some of these pellicles should be stained and mounted with the insect itself, as they often afford useful characters for the differentiation of closely allied

species. In the absence of male puparia it is often difficult to decide whether a certain species should be included in the genus *Aspidiotus* or *Diaspis*. Examination of the larval and nymphal pellicles of the female will usually decide this point, for in *Aspidiotus* the dorsal half only of the pellicle is present in the scale, whereas in *Diaspis* the venter remains attached and will be found beneath the posterior extremity of the pellicle.

In the genera *Aonidia*, *Fiorinia* and *Leucaspis*, the adult female is completely enclosed within the nymphal pellicle, and it will be necessary to break this open (with a fine needle) to obtain the actual insect.

Insects of the genus *Asterolecanium* require very careful handling. The derm is exceedingly thin and delicate. A very short immersion in boiling potash is sufficient to soften the tissues and decompose the contents of the body. I find it best to place the complete scale in the potash and continue the boiling only until the secretionary matter is dissolved, when the insect—now freed from its covering—should be immediately transferred to distilled water.

The treatment must be modified when dealing with adult males of any of the smaller species. Boiling in potash results in the hopeless crumpling of the wings and their entanglement with the other limbs. For such delicate objects a more prolonged immersion in cold potassium hydrate is preferable.

The procedure may be roughly summarised as follows:

(1) Boil in potash for a few minutes, or immerse in cold potash for a longer period, until the contents of the body are completely softened.

(2) Soak in distilled water for 24 hours.

(3) Press out the softened contents, and clean the surface parts.

(4) Mount temporarily in dilute glycerine.

(5) Stain with fuchsin, for 24 hours.

(6) Fix stain with picric acid for 5 or 10 minutes.

(7) Wash and remove superfluous stain in 70 % alcohol

(8) Wash in absolute alcohol.

(9) Place in oil of cloves for 10 minutes.

(10) Mount finally in canada balsam.

4. *Preservation of Unmounted Specimens.*

A few hints for the preservation and storing of unmounted material may be of use.

Desiccation is the method usually adopted and—for a general collection—is certainly the most convenient; though, where it is desired to retain the exact form of the fresh insects, it may be advisable to preserve duplicates in alcohol or dilute formalin.

A very large number of species, *e.g.* all the *Diaspidinae* and the flatter forms of *Lecanium*, may be treated like botanical specimens, *i.e.* dried, together with the leaves to which they are attached, between absorbent paper. But the pressure employed should be light—merely sufficient to keep the leaves flat. I frequently have material submitted to me for determination, where no pressure at all has been employed, with the natural consequence that the leaves are so curled or shrivelled that the task of examination is greatly aggravated. In such cases it is necessary to break up the whole material and to examine it very closely or valuable specimens may be overlooked. A leaf that has been dried flat may be completely examined with the maximum of convenience in the minimum of time. Thin slices of bark, or rind of fruits, may be treated in the same way. Twigs bearing specimens may be cut up into convenient lengths and dried without pressure. In any case, superfluous and useless parts should first be removed, to facilitate subsequent examination and save space. Leaves bearing hemispherical or highly convex species may be dried flat without pressure by pinning down the edges. Species that are not habitually attached to their host plant, such as many species of *Pseudococcus*, *Orthezia*, etc., are best removed and dried separately, after which they may be kept in small glass tubes plugged with cotton wool, or, better still, in the small gelatine capsules supplied by chemists for the reception of various drugs. Specimens dried *in situ* should be wrapped in soft paper and placed in small envelopes upon which the full data should be written. Capsules or tubes should be placed in similar envelopes. The envelopes themselves may be conveniently stored in white cardboard boxes which should be made to order and should be of various sizes which must be multiples of the smallest unit. The sizes that I have adopted in my own collection are:

$$1\tfrac{3}{4} \times 2\tfrac{3}{4} \times \tfrac{1}{2}\ ; \quad 1\tfrac{3}{4} \times 2\tfrac{3}{4} \times 1\ ;$$
$$1\tfrac{3}{4} \times 2\tfrac{3}{4} \times 2\ ; \quad 1\tfrac{3}{4} \times 2\tfrac{3}{4} \times 4.$$

The drawers of my cabinet have an inside measurement of $17 \times 16 \times 2$ inches deep, each of which will hold six rows of 30, 15, 8 or 4 boxes, according to the size. With the exception of the largest size, the boxes stand edgeways in the drawer.

Each box should be reserved for a single species only, but may contain several gatherings of that species. The name of each species should be clearly indicated on the cover of its particular box. The various genera will naturally be grouped in their respective families, but it will be found convenient to arrange the species alphabetically, under their respective genera. A small quantity of finely powdered naphthalin should be placed in each box, and renewed periodically. If preferred, naphthalin dissolved in petrol or benzine may be employed. A few drops of this liquid will spread over the bottom of the box and, upon evaporation, will leave a fine deposit of naphthalin which has the advantage of not shifting its position when the boxes are placed on edge.

Specimens preserved in a liquid medium (for which alcohol of about 80 % or formalin diluted to about 3 % may be employed with satisfactory results) must be kept in tightly corked tubes. These do not lend themselves so conveniently to arrangement in the general collection. They must be stored in separate racks, or in boxes fitted with compartments for the purpose.

Glass slides with microscopical preparations can be stored in any of the various forms of boxes or cases designed for the purpose. I use cases made in book form, each case containing 50 slides, with an index on the inside of the cover. Such cases can be arranged like volumes on book shelves.

Surplus material should always be retained, for purposes of exchange. Great convenience and economy of time will be experienced if such duplicates are at once portioned out and placed in labelled envelopes, ready for distribution when required, instead of being stored in bulk. When an application for specified duplicates is made by some correspondent, the time required to go through a large collection, separate out the required material, do it up in packets and label it, is often greater than can be given at the time. The task is therefore postponed for some more favourable opportunity which may be indefinitely delayed. I keep all my duplicate material in small labelled envelopes which are stored (alphabetically) in tin boxes made especially to fit them. Any species can then be found instantly and is ready, without further attention, for distribution.

5. *The Importance of Exact Measurements.*

Finally, I should like to say a few words on the importance of exact measurement in critical comparisons. For this purpose a camera lucida is almost indispensable. Take, for instance, the determination of the antennal formula. Direct measurement of such minute parts is extremely difficult; but, if enlarged camera drawings are made, they can be compared and measured with the greatest facility. Neither the eye alone, nor freehand drawings can be trusted implicitly. Body measurements alone are not of much value between closely allied species, as individuals from a single colony often vary considerably in size, and such variability is still more marked between examples collected on different plants. But the more densely chitinous parts—antennae, limbs, anal lobes, etc.—are much more constant. After the final moult these organs do not increase in size, though the body of the insect may more than double its original dimensions.

PLATE III

General view of the machine showing main pipe.

[Photo by Clarke & Hyde

The motor pump.

Mixing wash. [*Photo by Clarke & Hyde*

Using telescopic ladder.

Spraying the tallest trees.

Lifting the motor.

Coupling main pipes.

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PRELIMINARY NOTES ON DAMAGE TO APPLES BY CAPSID BUGS.

BY J. C. F. FRYER, M.A.,

Entomologist to the Board of Agriculture,
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(With Plates IX and X.)

THAT plant bugs of the family Capsidae can be responsible for a serious form of injury to apples has been recognised in this country for several years. Cases have been recorded by Theobald [1] and by Collinge [2] while complaints have been received from time to time by the Board of Agriculture from fruit growers in various parts of the country. On the continent brief references can be found to the Capsidae, notably to the genus *Lygus*, in most works on economic zoology, but the precise form of injury here dealt with does not seem to have been generally recognised. In America members of the Capsidae are well known as pests to both apples and pears and, though with the exception of *Lygus pratensis* Fab. the species there are not those found in Europe, yet the type of injury produced seems to be much the same. In this connection attention may be drawn to the papers of Taylor [3] on *Lygus pratensis*, of Crosby [4] on *Heterocordylus*[1] *malinus* Reut. and *Lygidea mendax* Reut., and of Caesar [6] on the two latter species and on *Neurocolpus nubilus* Say. and *Paracalocoris colon* Say. where full accounts may be found both of the insects and the injuries they produce. It will suffice to point out here that at least one author, Caesar, has found some difficulty in showing which of the various species found on apples are actually responsible for the damage and that while Crosby in the U.S.A. lays most of the blame on *H. malinus* and *L. mendax*, Caesar in Canada attributes the injury primarily to *N. nubilus* and *P. colon*, treating the two previous species as of secondary importance. The difficulty in the identification of the actual cause of the damage has also been felt

[1] An allied species, *H. flavipes* Matsuma damages apples in Japan. Nitobe [5].

in England and this paper is intended partly to throw more light on this question—though it has for its primary object the attraction of more attention to the subject at large, since the actual loss which may result from the attacks of Capsids is very serious.

As in the case of most plant bugs (*L. pratensis* is sometimes an exception) the primary cause of the damage is a puncture made by the bug in feeding. The juices of the plant are drawn up through this wound and either on account of the direct loss of sap or possibly from the injection of some irritant poison the surrounding tissues are more or less injured, the extent of the injury varying with the condition and portion of the plant attacked. In the case of apples the injury takes place very early in the season, probably before the blossom opens, when the tissues of the developing fruit and foliage are soft and in a state of rapid growth. The bugs responsible have then but recently been hatched and are very small; they appear to feed equally on the young fruit, foliage and young shoots, all of which suffer to some extent, though the injury to the fruit is the serious feature. The puncture of the bug appears to cause a definite check to the surrounding tissues so that, as the fruit grows, some parts develop more rapidly than others and a badly shaped, distorted apple is formed. When the check is very severe all growth ceases near the wound and as the remainder of the fruit swells rapidly a crack appears and may extend the whole length of the apple. A further feature often present is a more or less extensive discolouration or "russetting," which seems to arise from the abnormal development of the damaged cuticle. Finally the surface of the fruit may show a number of small pimples which so far as is known at present are the result of the unhealthy healing of the punctures. In the young fruit the actual puncture is readily seen but later it becomes obliterated and there is not as a rule any discolouration in the flesh of the apple as described by Caesar in the Canadian attack. It will be noticed that some of these forms of injury may also appear from other causes and are not infrequently attributed to some climatic action, as for instance to cold winds or excessive moisture. Although it seems probable that Capsid injury is more common than is generally supposed, at the same time it is obvious that all checks to the developing tissues of the fruit would be likely to produce very similar results so far as the mature fruit is concerned.

The injury to the foliage is perhaps more definitely diagnostic of an insect attack. As in the case of the fruit the puncture affects the surrounding tissues so that an attacked leaf shows numerous brown

spots, usually near its base, where the proboscis of the bug has penetrated. The leaf is frequently undersized and badly shaped and when it becomes old the small patches of dead tissue round each puncture may fall away, producing a very ragged condition. Distortion of the young shoots has been noticed by Theobald and this feature of the attack was also observed in 1913. All damage to both fruit and foliage is completed early in the season and though the bugs continue to puncture the foliage little harm seems to ensue.

The sum of the damage detailed above is very considerable. The injured fruit is almost unsaleable and cases were visited where 30 %–50 % of the crop was stated to have been affected, and in this estimate no account was taken of fruit so damaged that it fell off before reaching maturity. A further serious feature of the attack is that it seems to preserve a high intensity for several years consecutively in the same orchard and is not like the many diseases which vary within wide limits year by year.

In distribution, this Capsid attack is very local and is not known to be widespread in any district; at present it is known to occur sporadically in Kent, Suffolk, Nottingham, Worcester and Hereford.

As regards the different varieties of apple it is not possible yet to say that any kind is either immune or specially susceptible, since facts obtained from one affected orchard were negatived by observations in the next. It certainly appeared that the trees in the affected orchards were not in a good state of health. Mr G. P. Berry, of the Board of Agriculture, examined all the affected orchards and he was able to confirm this view. A number of soil analyses were therefore made in the hope of obtaining further light in this direction, but the work was fruitless for the soils in most cases showed no marked deficiencies in composition or other disability adequate to explain the apparent low state of health. It is still felt however that this side of the problem offers material for investigation since a tree not in a flourishing condition would naturally be less able to withstand the Capsid punctures than a healthy tree.

Turning next to the problem of the species of Capsid responsible for the damage, a few notes may be given on a somewhat cursory survey of four of the affected orchards, all of which are of large size and have suffered greatly from the disease for several seasons consecutively. An ordinary Bignell beating tray was used to obtain specimens and attention was paid to insects which were present in large numbers or belonged to a species to which the damage had previously been attributed. These

species are (1) *Lygus pratensis* Fab., (2) *Psallus ambiguus* Fall., (3) *Atractotomus mali* Mey., (4) *Plesiocoris rugicollis* Fall., (5) *Orthotylus marginalis* Reut. The first of these, *L. pratensis,* may be dismissed at once from the enquiry since only one or two specimens in all were found in the affected orchards. Its mode of injury too, as described by Collinge and Taylor, differs from that actually observed, and consists in a dimpling of the fruit. *L. pratensis* is a species which hibernates as an adult, and lays eggs in the early spring ; occasionally these eggs are laid under the cuticle of the young apple, and as the fruit grows a dimple is formed, which persists until the fruit is mature. In the case of this species, therefore, the injury is not always the result of the punctures made by the bug in feeding.

As regards the other species just mentioned, their distribution in the affected orchards may be seen from the accompanying table. In the same table a few selected unattacked orchards are given to show which species may be present in an orchard without producing injury.

	Psallus ambiguus	*Atractotomus mali*	*Orthotylus marginalis*	*Plesiocoris rugicollis*
1. Suffolk affected	X	X	O	X
2. Worcester affected	X	O	X	X
3. Worcester affected	X	X	X	X
4. Worcester unaffected ..	X	O	X	O
5. Nottingham affected	X	O	X	O
6. Hertford unaffected	X	X	O	O
7. Cambridge unaffected ..	X	O	O	O

NOTE. In No. 3 *O. marginalis* was scarce. In No. 4 two specimens only of *O. marginalis* were obtained. In the other cases the " X " implies that the species was exceedingly abundant, the " O " that it was absent

Taking these species singly it will be seen that *P. ambiguus* was found abundantly in all orchards and can hardly be the cause of the damage. It is a small brown or red species which is usually very common on apples everywhere.

The second species, *A. mali,* was considered by Theobald to be responsible for injury in Kent ; in the present case it was absent from two affected orchards, present in the other two, but also present and in large numbers in an unaffected orchard. It is not therefore considered here to be a markedly injurious species. In colour and shape it somewhat resembles *P. ambiguus,* but may at once be known by its small size and thickened antennae. The third and fourth species, *P. rugicollis* and *O. marginalis,* may be considered together. Both species were present in two of the affected orchards and in each of the other cases of attack

one or other was present. Further they were absent from the unaffected orchards with the exception of one in Worcester where *O. marginalis* was recorded as present from two specimens only. It therefore appears that one or both of these species are responsible for the injury, and this opinion is strengthened by an experiment carried out by the proprietor of an affected orchard in Worcester. This experiment consisted in excluding the larvae of these species from a number of trusses and also in enclosing them with others. The trusses from which the bugs were excluded developed sound fruit, while the apples enclosed with them sustained typical capsid damage. It is hoped to repeat this experiment with *P. rugicollis* and *O. marginalis* separately, in order to confirm suspicion as to their both being responsible for damage—in the meantime they must be left to share the responsibility between them. In colour *O. marginalis* and *P. rugicollis* differ from *Psallus* and *Atractotomus* in being green or yellowish-green ; they closely resemble each other superficially and may easily be confused in the field. The presence of a rounded ridge or collar towards the anterior margin of the pronotum will always distinguish *P. rugicollis* from an *Orthotylus*, while in addition the former species is broader and stouter than the latter, characters which give it a somewhat different appearance. Both species are on Theobald's list of suspects, in his articles on the subject, in the *Journal of Wye College*, which also contains a quotation from Schoyen to the effect that these species are harmful to apple and currant in Sweden. Of neither species is the life history known. Mr E. A. Butler, who was consulted on the subject, kindly gave the information that both species were usually found on willow or alder, though Reuter, who described *O. marginalis*, mentions apple as one of its food plants. Further, in Mr Butler's experiences, these species appear rather late in the season, larvae being found in June and July, and adults at the end of the latter month and in August. In the cases now under consideration, *P. rugicollis* was adult in Suffolk on the 13th June and one or two pairings were then observed. *O. marginalis* was adult in Worcester on the 24th June, but many specimens were still immature, and it appears to be a later insect than *P. rugicollis*. Both species, however, must have hatched towards the end of April and there is thus a considerable discrepancy between the observations here recorded and those of Mr Butler. The possibility of two broods naturally suggested itself but this is considered as most unlikely by authorities on the Hemiptera. Examples sleeved on apple trees in June failed to produce a second brood, and up to the present no eggs have been discovered, and their exact situation is unknown. It is assumed temporarily that apple has

somewhat recently been adopted as a food plant, and that this change has brought about an alteration in the time of appearance of the insects. However this may be, it is evidently useless to speculate on the biology of these species without further observations and this paper may be concluded by a reference to the very meagre notes on "treatment" which have been gathered.

Since the damage is done soon after the insects leave the egg it is evident that any treatment by means of spraying must be carried out at exactly the right time, and the spray must of course be one which kills by contact. Crosby, in America, found that paraffin emulsion, whale-oil soap and lime sulphur were of little service. Preparations of nicotine and soft soap gave fairly good results and were recommended with the caution added that the trees must be very thoroughly drenched with the wash. The spray was to be applied both before the blossom opens and after it falls. In England, a wash of this nature has been found partly successful, but in one case no benefit whatever resulted, the reason given being that the bugs hatch out over a long period. In this case, both species were present and if *O. marginalis* is later in appearing than *P. rugicollis*, it is probable that this explanation is correct. The possibility of a winter wash against the eggs is hardly worth considering, for apart from the failure of winter washes against insect eggs in general, it will probably be found that the eggs of these bugs are deeply imbedded in the bark of the twigs, quite out of the reach of all sprays. The problem of dealing with these bugs in some ways resembles that of the apple sucker (*Psylla mali*) and is likely to be as difficult. At present, therefore, the only treatment which can be suggested is a spray of soft soap and nicotine, or possibly soft soap and quassia, but success will depend on a nice estimation of the exact time to apply the wash, and the thoroughness with which the application is made. Cases such as this bring out clearly the need for further experiments in insecticides, especially in "contact" insecticides, with the object of finding an efficient substitute for the expensive nicotine and if possible of increasing the number of reagents from which to choose.

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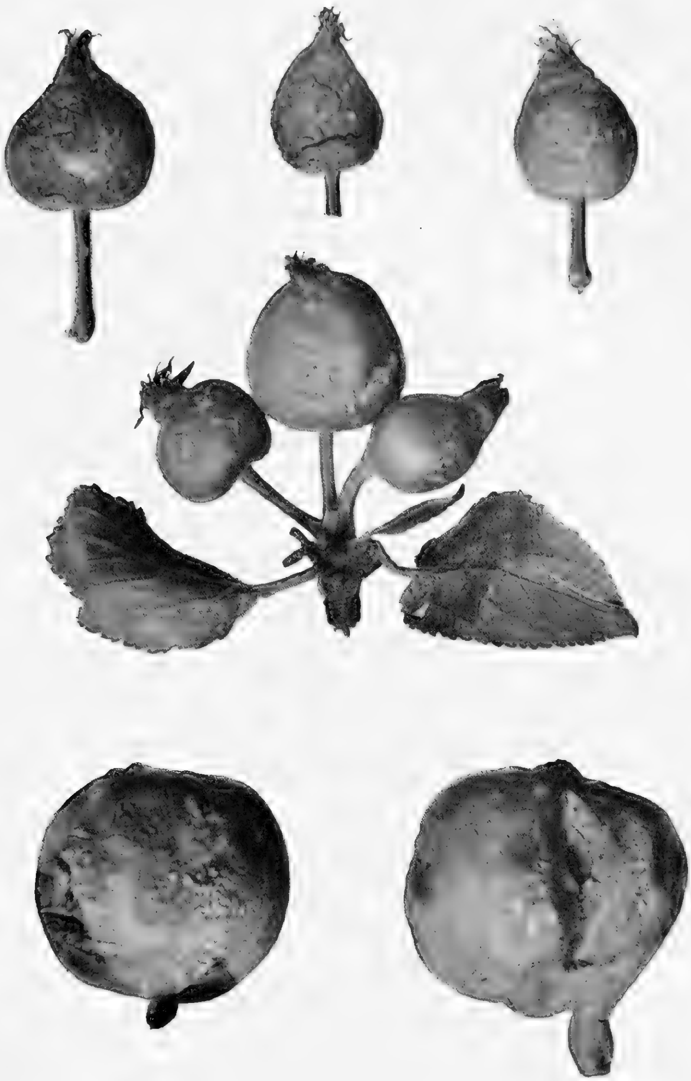
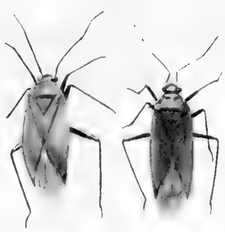


Apples to show distortion and cracking due to punctures by Capsid bugs. Natural size.



A.

B.

C.

D.

E.

Fig. *A.* *Plesiocoris rugicollis.* Fig. *B.* *Orthotylus marginalis.* Fig. *C.* *Lygus pratensis.* Fig. *D.* *Atractotomus mali.* Fig. *E.* *Psallus ambiguus.* Each specimen × 3.

THE INTERNATIONAL PHYTOPATHOLOGICAL CONFERENCE, 1914.

By A. G. L. ROGERS

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The International Phytopathological Conference which was opened at Rome on the 24th February last and was brought to a conclusion on the 4th March, is the outcome of a long agitation. According to the *Report* prepared by M. Louis Dop, and circulated to the Delegates before the Conference began, the first proposal for international action was made by Professor Eriksson as far back as 1880. Similar proposals were made from time to time at different International Congresses, but with little result, except that at the Seventh Congress of Agriculture, held in 1903, a special Committee on plant diseases was formed, and the *Zeitschrift für Pflanzenkrankheiten* started as their official organ, under the editorship of Professor Sorauer. The publication is, however, international only in the sense that papers from authors of any nationality are accepted, and the Governments of the chief states are in no way involved. The first real step towards international action was taken in 1905, when the Institute of Agriculture was founded at Rome, and the subject of plant diseases definitely included among the subjects with which it was competent to deal. Further progress was made when the French Government were invited by a resolution passed at the International Congress for Comparative Pathology at Paris in 1912, to take the initiative by calling an International Phytopathological Conference at Rome. Invitations were sent out for a meeting in 1913, but the notice given was inadequate, and the meeting was postponed till 1914. The Conference which has just been concluded is therefore very largely due to the action of the French Government, and certainly the initiative was taken by the French delegates throughout the proceedings. M. Develle, a former Minister of Agriculture, was elected

President of the Conference at the opening meeting, and M. Louis Dop, the permanent representative of France at the International Agricultural Institute, took a prominent part in the direction of business. The chief credit, however, belongs to the French technical delegates, headed by M. Mangin, whose persistence and readiness in debate, coupled with his fertility in devising expedients for overcoming difficulties, carried all before him. The prominent position occupied by the French delegates in the Council chamber, and the fact that the discussion was carried on in their native language, and in accordance with the usage of their Parliamentary procedure, no doubt gave them a great advantage over other delegates, an advantage, however, which they never abused.

As many as 30 States were represented, and the Conference was informed that certain other countries accepted the principle of an International Convention in advance. The only notable sovereign state unrepresented was the United States of America but no delegates were sent by South Africa, Australia, New Zealand, or any of the smaller colonies. The instructions given to the three English delegates were simple. We were not authorised of course to commit our country to any binding agreement, but this was the less important because it was made very clear at the beginning of the debate that no delegate had such powers, and that no proposal would be made which would not be submitted for the approval of our Government through the Foreign Office, for subsequent ratification by plenipotentiaries appointed for the purpose. We were authorised, however, to accept on behalf of the Board, the principle of a Convention, and to press for three cardinal points: (1) that plants coming from a nursery that had been inspected and found free from important diseases, should be allowed entry if accompanied by an official certificate of health, and that it should not be necessary that each consignment should be specially examined; (2) that the certificate should specify the diseases for which the nursery had been examined, and (3) that consignments accompanied by the official certificates should not be detained at the frontier for re-examination by the officials of the country of destination. It was thought that if we could secure these points, the hindrances to trade, which had in recent years grown up in so many countries, would be removed, and that a wide field for the development of English commerce in plants would be opened. As events turned out, we had singularly little difficulty in getting these principles conceded. The first two points were pressed for by the delegates of other countries, and were agreed to without opposition, and though the delegates present

would not agree to surrender entirely the right of examination on arrival, the first delegate of England pressed our claim so skilfully that an assurance was understood to be given that the right would rarely be exercised if it was found that the inspection in this country was thorough and the consignments were found to be healthy. It is most improbable that any further concession would have been gained by pressing the claim any further.

The Convention which was ultimately drafted, and signed by all the delegates present, may be summarised as follows. Adhering States pledge themselves to form at once, if they have not already done so, an official service of inspection of all nurseries, glasshouses and other establishments offering plants for sale. They shall be prepared to issue phytopathological certificates, control the movement of plants, and the methods of packing and means of transit of the same, organise a service for the suppression of dangerous diseases, and otherwise fulfil the usual functions associated with a phytopathological department of State. No State can adhere unless this is done at once. But it must also undertake to create within two years, if it has not already done so, one or more institutes for enquiry and research, obviously so that the Administrative Department may be supplied with the best scientific and technical advice possible. The State must pledge itself to issue certificates with all consignments of plants sent abroad and to receive consignments accompanied by such certificates from other adhering States, and better terms must not be given to States that do not adhere than to those that do, while States with common borders may make special arrangements with each other with regard to the movement of plants. All this is elemental, and no Convention would be possible without some such agreement. But the really important point of the Convention consists in the way in which this system is to be applied. It was agreed with very little discussion that the Convention should not apply to certain kinds of plants. Grain, seeds, potatoes, onions and general farm produce—articles de grande culture—to use the exact words, are excluded. Presumably, States may make their own regulations as regards such produce, but it was generally felt, I think, that it would be inadvisable in most cases to make any regulations at all. Most delegates felt that the service at present in force in their own country would be incapable of such a system of inspection, as would make the certificates of any real value. Vines also were excluded as being dealt with under the Berne Convention, to which every State that joined the Rome Convention would be expected to adhere. On the other

hand, a vigorous stand was made for the inclusion of cut flowers and bulbs of the flowering kind, a matter which is likely to give some countries a good deal of trouble. Finally, an important discussion took place on the diseases for which inspection is to take place. A single certificate of health was felt to be insufficient; a list of diseases prepared by the Conference too fruitful a subject for dispute; and after a short debate it was unanimously decided to leave each country to prepare its own list of the diseases against which it wished to be protected. The preparation of this list will be a matter of extreme difficulty, and may have an important bearing on the nature of phytopathological research. But the really important article is that which lays down the rules on which the list is to be prepared. This article was drafted by a special Sub-Committee though modifications were introduced when the report was presented to the Committee and, as far as my recollection serves, at the final sitting of the Conference. It prescribes that the list is to be as restricted as possible, that no pests are to be included whose host plant is not to be found in the country of destination, and that the common pests whose distribution have been widespread in almost every country for many years are to be excluded. This in itself would be sufficient to keep the list from being unduly long, since few people could be found who would object to the inclusion of such pests as could properly fall within the category left open. But in order to emphasise the limitations two further definitions were proposed. On the motion of one of the Danish delegates it was decided that the pests must be capable of being easily conveyed by living plants or parts of such plants, and on the suggestion of one of the English delegates it was agreed that the pests must be epidemic in character, and destructive or at least injurious to the plant. It was explained that destructive meant destructive to the life of the plant, and that injurious meant destructive to the commercial value of the crop, or to that part of the plant for the economic use of which the plant itself is cultivated. This article would prevent such a pest as *Nectria ditissima* being included, though it appeared on several of the provisional lists presented by delegates present at the Conference, since it is not only of old standing and general distribution but it cannot be said to be destructive to the tree or to the crop it bears. There are plenty of apple trees in this and other countries, which have been cankered for many years and yet continue to bear a serviceable crop of fruit.

The proposed Convention is not a very drastic affair, and it is quite as likely to be attacked on the ground that it does not go far enough

as on the score that it goes too far. But for many reasons, I think it is a great step in the right direction. It establishes the principle of international action in the first place, and of international unity in the second. It implies direct administrative effort to control dangerous plant diseases, and it checks excessive and unreasoning restrictions. It is based on the principle of mutual trust, and the procedure contemplated is the productive method of the eradication of disease at home in place of the present wasteful system of inspection of foreign consignments. It will, I hope, promote trade and not hinder it. It will benefit both the nurseryman and the consumer. These considerations cannot be overlooked by administrators and pure economists. But on this occasion it is natural that other questions should be asked. Scientists may well demand whether it will promote the cause of learning, and encourage research or if it will by establishing administrative rules and procedure, which will tend to become stereotyped and inelastic, hinder the application of new scientific discoveries and become a bar to progress. It is difficult to forecast the future. We all know how the wisest laws, if maintained after the need for them has ceased, prove instruments of reaction, and it is impossible to say that no flaw will ever be found in this Convention, or that it will never be open to criticism. There are some people who object to State action in such matters on principle, and others who do not believe that regulations can check the spread of disease. Such persons will no doubt view the whole idea of a Convention with disapproval. But to those who are prepared to accept the principle that epidemic diseases can be checked by State action, and probably by State action alone, I would point out that this is the first time that any Convention, so far as I am aware, has made it an essential part of the obligations of each adhering State, that scientific research must be associated with administrative action : that this Convention gives economic biology and phytopathology a status they never had before, and both directly and indirectly offers a new field for scientific research.

THE HOST PLANTS AND HABITS OF *APHIS RUMICIS* LINN., WITH SOME OBSERVATIONS ON THE MIGRATION OF, AND INFESTATION OF, PLANTS BY APHIDES[1].

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Introduction.

The following experiments are the first of a series of experiments and observations on the habits and life-history of the Aphididae, which the author hopes to carry out, with the hope that our knowledge of the migratory habits of these insects, and the infestation of plants by them, may be increased.

The results obtained this season do not afford sufficient data upon which to base any definite explanations of these problems. Many of the observations, however, have suggested certain lines of enquiry.

In the latter part of this paper, the author has briefly discussed some of the factors which may underly the questions of the migration of Aphides and the infestation of plants by them.

Some tentative suggestions as to the nature of these factors have been made, with the hope that deeper enquiries into the habits of this important family of insects may be stimulated. These suggestions are based upon observations made in connection with these experiments.

In September, 1912 (*op. cit.* below), Theobald published an interesting paper dealing with the habits and life-history of *Aphis rumicis*, in which this author describes a double life-cycle for this species. In one cycle ova are produced by the sexuparae, in late Autumn, on Rumex plants. These ova hatch out in Spring, and subsequently winged migrants are produced on the Rumex plants. These migrants go, about June, to

[1] The species of Aphis used is the black aphis found in spring on *Euonymus europaeus* (*Aphis euonymi*). It is now considered as one of the many synonyms of *Aphis rumicis*, *vide* Theobald, F. V. (1912), *Journ. Bd. of Agric.* vol. XIX, No. 6, Sept. 1912, pp. 466–476.

Broad Beans, which plants they heavily infest throughout the Summer. In Autumn the winged migrants from the Broad Beans return to Rumex, sexuparae being produced in late Autumn, and subsequently ova being laid on the Rumex plants.

In the second life-cycle, ova are produced by the sexuparae on Euonymus in late Autumn or Winter, which hatch out in Spring. The winged migrants subsequently produced migrate to Poppies in June, which plants they heavily invest as *Aphis papaveris.* In some years, when the number of Aphids produced is abnormal, some of the migrants go from the Poppies to Mangolds and many plants of the Chenopodiaceae family. In Autumn the winged migrants return to Euonymus where sexuparae are produced and ova laid.

The aphids taken from these different plants showed no structural differences, although they differed slightly in size or colour on the different host plants.

It seemed to the present author that, if these two parallel life-histories for *Aphis rumicis* were stable, the question of the influence of the host plants on aphids is an important factor. The two life-cycles seemed to show that the preceding host plant upon which a generation of aphids is produced, has a determining influence on the species of plant subsequently selected by the winged migrants.

Theobald found that winged viviparous females taken from Euonymus lived on Broad Beans, and gave rise to the " bean black fly," but from field observations he was unable to trace whether the winged migrants from Euonymus went to Broad Beans.

This seemed to the present author to be a very important question in connection with the two life-cycles described for *Aphis rumicis.* It intimated that the two parallel life-cycles might be merged into one by crossing from Euonymus to Broad Beans, and from Rumex to Poppies. If the two life-cycles proved to be absolutely constant and separate, a very important feature would be established, namely the establishment of two biological species (*A. euonymi* and *A. rumicis*), both resembling each other in structure but differing physiologically in habits.

As the results obtained in these experiments will show, *Aphis euonymi* will heavily infest Broad Beans, and *Aphis euonymi* reared on Rumex will heavily infest both Broad Beans and Poppies. Thus the two life-cycles may be merged into one. The life-history, however, has not been completed, as owing to leaving England in September, I have been unable to trace the history of the sexuparae. However, the plants are still under observation, and the ova will be looked for in due course.

In concluding this general introduction, it may be added that the experiments, series *B* and *C*, have been carried out as far as possible under natural conditions.

The plants in the pots in series *A*, did not in some cases flourish as well as might have been expected, owing to the dry summer.

Experiments. Series A, B and C.

The aphis species used in series *A*, *B* and *C*, is the Black Euonymus Aphis (*A. euonymi*). All the aphids used in the first two series were reared from a small colony found in January (27. 1. 1913) on a small Euonymus bush in a garden near Richmond. In this way one was quite certain that the same species of Aphis was being used throughout, and further one knew exactly the history of the different generations produced as the various plants were infected.

The original colony on Euonymus was taken to the College greenhouse, and the plant covered with a muslin bag. When winged forms were produced, a clean Euonymus plant was infected.

The experiments have been made in three series, *A*, *B* and *C*, and have been carried out at Acton Lodge, Brentford, Middlesex, the experiment orchard for the Department of Economic Entomology, Royal College of Science, London. My sincere thanks are due to Professor Maxwell-Lefroy for the kind and generous way in which he has given me every facility for carrying on the work.

The notes and observations given under the various dates will show the results obtained.

Experiments. Series A.

The various plants indicated below, were infected with winged viviparous females in every case, except in the case of Rumex, No. 2, the aphides being transferred by means of a fine camel hair brush. The plants were raised in pots from seed and kept covered with muslin bags so that they were quite proof against external infection. During rainy weather the plants were kept in a partly closed frame, but otherwise they were kept in the open as much as possible. Observations were made from time to time and notes made as given below.

It will be seen in experiments, series *A*, that the chief food plants of *A. rumicis* have been infected from different hosts; thus, plants Nos. 1, 2, and 3, were infected with aphids bred on Euomymus, plant *B*. Similarly plants Nos. 4, 5 and 7 were infected with aphids bred on plant No. 1, and so on.

NOTES AND OBSERVATIONS ON PLANTS IN SERIES A.

Plant No. A. Euonymus europaeus.

Found infected with a small colony of *A. rumicis*, at Richmond, 27. 1. 13 and transferred to College greenhouse. The colony developed, and about the middle of February, many winged viviparous females were produced. These swarmed over the plant which became heavily infested. At the end of February, the aphids swarmed over the plant in vast numbers. Many of them died off. The winged forms crowded round the muslin bag, as though wanting to escape, and dissatisfied with the plant. Many of the young shoots of the plant were killed, and the aphids all died. The plant was kept covered till May 23rd, on which date there were no living aphids present. It was then reinfected with *Aphis euonymi*, from some Euonymus trees in Acton Lodge garden, and they produced several small colonies on the young growing shoots of this plant.

It should be noted that owing to a hard frost occurring early in February, the greenhouse was heated at night so as to make sure that the aphids would not die. This doubtless hastened the production of winged forms.

Plant No. B. Euonymus europaeus.

This plant was infected from No. *A*, about the third week in February, with three winged viviparous females. They produced colonies of apterous females. Winged viviparous females (2nd generation) appeared on this plant on April 27th. By the 20th May, the aphids were very numerous on this plant, and both the apterous and viviparous females were actively running over the plant, on the stakes supporting the muslin bag covering it, and crowding over the muslin, as though wanting to escape. By the end of the first week in June, many of the aphids were dying off. The aphids were much smaller than the members of the original colony, this no doubt produced by the fact that they were not feeding on the plant. Some specimens of the winged forms, which I preserved at this stage, show that the abdomen is small and shrunken in appearance. The apterous forms were also small, and present in extraordinary numbers. Contrary to their usual sluggish habits, they were actively running over the stakes supporting the muslin cover.

On May 5th, I put one apterous viviparous female from *B* on a clean branch of a small Euonymus bush, and on another branch I put a winged viviparous female from *B*. These both produced lice in 3 days, and although the numbers produced, even after a month, were very few, yet the individuals looked fat and healthy.

Plant No. 1. *Rumex sanguineus.*

5. 5. 13. Infected from Euonymus *B*, with 4 w. viviparous ♀'s.

7. 5. 13. A few aphids produced.

22. 5. 13. Many colonies present; collected round the apex of the young shoots, also several colonies along the mid-rib of the leaves. Some of the apterous forms are a smooth, shiny, jet black, colour, but many of them are covered with a mealy bloom.

26. 5. 13. A few winged forms produced.

29. 5. 13. The aphis infests the stem in vast numbers, almost along the whole of its length, also beneath the leaves along the mid-ribs. They are big, healthy individuals, the winged forms being much larger than those present on Euonymus *B*. Most of the winged forms are actively walking on the muslin cover as though wanting to escape.

4. 6. 13. Enormous numbers of winged forms are now present, crowding round the top of the muslin cover, and not on the plant at all. It is noticeable that during the progress of the infestation, the colonies of apterous forms first collected at the apex of the young growing stem, and gradually extended towards the base, until the whole stem was covered. Many also along the mid-rib, and main veins of the leaves.

24. 6. 13. Plant dead, all the aphids dead.

Plant No. 2. Rumex sanguineus.

5. 5. 13. Infected from Euonymus *B* with four apterous viviparous females.

7. 5. 13. Several aphids produced.

22. 5. 13. Several colonies present on this plant, also nymphs of winged forms produced. Colonies present on mid-rib beneath the leaves.

26. 5. 13. A few winged forms produced.

29. 5. 13. Now fairly heavily infested, but numbers not so great as in case of No. 1; there are fewer winged forms present.

4. 6. 13. Aphids not nearly so numerous as in No. 1; chiefly collected at top of the stem, but one colony forming half-way down. A few winged forms present, walking on the muslin cover. Several colonies beneath the leaves, on the mid-rib and veins.

16. 6. 13. Plant fairly heavily infested; numbers of w. v. ♀'s, which are crowding round the top of the muslin cover. Infestation not so heavy as No. 1.

28. 6. 13. Plant heavily infested, vast numbers of winged forms actively crawling over the muslin cover. Many apterous forms clustered along the length of the stem, and beneath the leaves, along the mid-rib, many of these very small.

8. 7. 13. Plant dead, aphids all dead.

Plant No. 3. Broad Beans.

25. 5. 13. Infected from Euonymus *B* with five w. v. ♀'s.

27. 5. 13. A few aphids produced, but it would appear that the w. viviparous females from *B* are weak and are not producing happily. Reinfected with 3 w. v. ♀'s from *B*.

31. 5. 13. Only a few aphids present. Reinfected with four w. v. ♀'s from Euonymus *B*.

24. 6. 13. Many colonies produced, situated on the upper part of the stem and in axils of the leaves. A few nymphs of winged forms present. Aphids big and healthy.

28. 6. 13. Winged forms present.

8. 7. 13. Plants fairly heavily infested; many winged forms gathered at the top of the muslin cover.
14. 7. 13. Infestation heavy; many winged forms crowding in vast numbers on the top of the muslin cover.
24. 7. 13. Plant smothered with aphids; many dead; plants very sickly, leaves curled and of a dirty brownish colour.

Plant No. 4. *Broad Beans.*

27. 5. 13. Infected from Rumex No. 1, with four w. v. ♀'s.
31. 5. 13. Only a very few aphids produced, winged mothers dead. Reinfected with five w. v. ♀'s from Rumex No. 1.
Note. It is possible that the w. v. ♀'s taken from the Rumex were old, and had already laid a number of lice on that plant.
24. 6. 13. Many aphids present which are collected along the upper part of the stem. Winged viviparous females present.
28. 6. 13. Aphids numerous along upper part of stem. Many winged forms present, some settled beneath the leaves, but many collected in the top of the muslin cover as though wanting to migrate.
8. 7. 13. Heavily infested, great numbers of winged forms collected in top of muslin cover, aphids distributed all over the stem, and beneath the leaves.
24. 7. 13. Plants smothered with aphids; many winged forms dead; plants look sickly.

Plant No. 5. *Rumex sanguineus.*

31. 5. 13. Infected from Rumex No. 1, with four w. v. ♀'s.
18. 6. 13. Many colonies going on this plant, but it became diseased, and the leaves died, so the aphids were transferred to another *Rumex* plant.

Plant No. 6. *Shirley Poppies.*

4. 6. 13. Infected from Euonymus *B* with four w. v. ♀'s.
18. 6. 13. Several apterous viviparous females present, and one fairly large colony.
24. 6. 13. Several small colonies produced, but reproduction seems slow in numbers.
30. 6. 13. A few small colonies present beneath the leaves and on the stem, but numbers small.
8. 7. 13. A fairly good number of aphids present, along the mid-rib of leaves and on the stem, and flower stalks.
24. 7. 13. A good number of aphids distributed generally over the plants, which look sickly, and flowers almost over; several winged forms produced.
28. 7. 13. Many winged forms present; plants fairly heavily infested.

Plant No. 7. *Shirley Poppies.*

4. 6. 13. Infected from Rumex No. 1, with five w. v. ♀'s.
18. 6. 13. Several large apterous females present beneath the leaves, along the mid-ribs ; very few in number.
24. 6. 13. Several colonies present, beneath leaves, and on the stem.
28. 6. 13. Plants are rather poor specimens ; there are a few individuals collected along the stem, and beneath the leaves, but numbers small.
8. 7. 13. Several colonies along the stem and flower stalks, and beneath the leaves, along the mid-ribs.
12. 7. 13. A few winged viviparous ♀'s produced.
14. 7. 13. Several winged forms collected at the top of the muslin cover, as though wanting to escape. Many nymphs of winged viviparous ♀'s on the plants. Poppies in flower.
24. 7. 13. Infestation fairly heavy.

Plant No. 8. *Papaver rhoea.*

24. 6. 13. Infected from Rumex No. 2, with ten w. v. ♀'s.
28. 6. 13. Several aphids produced.
8. 7. 13. Several colonies going well beneath the leaves.
14. 7. 13. Plenty of colonies present along the flower petioles, and beneath the leaves ; winged viviparous females produced, and several nymphs of winged forms present.
24. 7. 13. Plants are healthy ; many aphids on the flower stalks, and beneath the leaves ; not very many winged forms produced.
28. 7. 13. Infestation moderate.

Plant No. 9. *Red Beet.*

25. 6. 13. Infected from Rumex No. 2 with ten w. v. ♀'s.
8. 7. 13. The plants Nos. 9, 10, and 11 are not growing well, and have wilted considerably owing to lack of water, so that the aphids seem to have died off. Reinfected with five w. v. ♀'s from Rumex No. 5.
14. 7. 13. A few isolated individuals present.
24. 7. 13. Several large apterous viviparous females present, collected on the underside of the very young leaves.
28. 7. 13. The apterous viviparous females are collected on one small young leaf ; they are large and healthy individuals, but up to the present do not appear to be increasing very much in numbers on these plants. No nymphs of winged forms or winged forms produced as yet.

Plant No. 10. *Mangolds.*

25. 6. 13. Infected from Rumex No. 2 with ten w. v. ♀'s.
28. 6. 13. One living winged form left, but owing to lack of water the plant has wilted, and aphids have not taken.
8. 7. 13. Only one or two individuals present. Have reinfected with five w. v. ♀'s from Rumex No. 5.

14. 7. 13. A few individuals present.
24. 7. 13. A few small colonies present on one young leaf, numbers few, four fat, healthy apterous females.
28. 7. 13. Aphids few in number; no winged females yet.

Plant No. 11. *Sugar Beet.*

24. 6. 13. Infected from Rumex No. 2 with eight w. v. ♀'s.
28. 6. 13. Plant has wilted owing to lack of water; a few young aphids present.
8. 7. 13. Reinfected this plant with five w. v. ♀'s from Rumex.
14. 7. 13. One colony going well beneath one young leaf, the individuals being healthy; a few individuals also present on the older leaves.
24. 7. 13. About 30 individuals present, collected chiefly on the underside of the leaves, along the veins.
28. 7. 13. Aphids chiefly collected on one young leaf, which is curled, but a few colonies on the older leaves. Winged forms produced, and nymphs of winged ♀'s present.
30. 7. 13. Aphids look healthy, but numbers up to the present are small.

Plant No. 12. *Onions.*

27. 6. 13. Infected from Broad Beans No. 4 with five w. v. ♀'s.
8. 7. 13. No aphids present, have left the plants and died.

Plant No. 13. *Red Beet.*

27. 6. 13. Infected from Broad Beans No. 4 with five w. v. ♀'s.
28. 6. 13. A few aphids produced.
8. 7. 13. One winged mother alive, but not many individuals produced, so reinfected with five w. v. ♀'s from Broad Beans No. 4.
14. 7. 13. A few small colonies formed on the young leaves.
24. 7. 13. Several big healthy apterous females present beneath the young leaves; a few nymphs of winged viviparous females produced.
28. 7. 13. Infection heavier than in case of No. 9, but numbers not great; winged forms produced.

Plant No. 14. *Shirley Poppies.*

27. 6. 13. Infected from Broad Beans No. 4 with eight w. v. ♀'s.
28. 6. 13. Several aphids produced.
8. 7. 13. Several colonies going well beneath leaves, on the veins; also a few individuals on the flower-stalks.
14. 7. 13. Poppies in flower; several colonies present beneath the leaves, and on the flower-stalks.
22. 7. 13. Winged viviparous females produced.
24. 7. 13. A fair number of aphids present, distributed along stems and flower-stalks; winged viviparous females present.
28. 7. 13. Many winged forms produced; infestation is moderately heavy.

Plant No. 15. *Shirley Poppies.*

27. 6. 13. Infected from Broad Beans No. 3 with five w. v. ♀'s.
8. 7 13. A few small colonies present on the veins beneath the leaves.
14. 7. 13. Several small colonies going on the veins beneath the leaves.
24. 7. 13. Aphids seem to be chiefly beneath the leaves; several nymphs of winged viviparous females produced.
28. 7. 13. Several of the leaves curling owing to aphid colonies below; nymphs of w. viviparous females present.
30. 7. 13. Aphids only in moderate numbers.

Plant No. 16. *Shirley Poppies.*

27. 6. 13. Infected from Broad Beans No. 3 with five w. v. ♀'s.
8. 7. 13. A few colonies present on the veins beneath the leaves; Poppies just coming into flower.
14. 7. 13. Several colonies on the flower-stalks and beneath the leaves; Poppies in flower.
24. 7. 13. A moderate number of aphids present; many winged forms produced; aphids infest the stem and flower-stalks, and also collect along the veins beneath leaves; Poppies still flowering.

Plant No. 17. *Swedes.*

27. 6. 13. Infected from Broad Beans No. 3 with five w. v. ♀'s.
28. 6. 13. A few aphids produced.
8. 7. 13. One colony of three or four individuals present.
14. 7. 13. A few isolated individuals going on the leaves, but numbers very few, and no colonies forming.

Plant No. 18. *Red Beet and Sugar Beet.*

27. 6. 13. Infected from Broad Beans No. 3 with five w. v. ♀'s.
28. 6. 13. Several aphids produced.
8. 7. 13. A few colonies present beneath the leaves, on the veins, on both plants.
14. 7. 13. Numbers very small, but several healthy apterous forms on underside of the young leaves of both plants.
24. 7. 13. Nymphs of winged forms produced; several small colonies of healthy individuals present beneath young leaves.
28. 7. 13. Aphids big and healthy but not many produced; chiefly collected on the very young leaves, but a few on older leaves; nymphs of winged forms present.

Plant No. 19. *Red Beet.*

27. 7. 13. Infected from Shirley Poppies No. 6 with five w. v. ♀'s.
4. 8. 13. A moderate number of young aphids present.
10. 8. 13. Not very many individuals present as yet.

The following plants were also infested as follows.

Plant No. 20. *Broad Beans.*

2. 6. 13. Infected from a Euonymus tree growing in Acton Lodge garden with four w. v. ♀'s.
24. 6. 13. Many aphids now going well on the plants, along upper half of stem, and some along mid-ribs beneath leaves.
26. 6. 13. Winged females produced.
28. 6. 13. Aphids heavily infesting the plants along the stems. Many winged forms present, which are walking over the muslin bag as though wanting to escape.
8. 7. 13. Plants heavily infested; very many winged forms crowding on the muslin cover.
14. 7. 13. Bean plants almost dead; leaves curled and brown; many aphids dead.
24. 7. 13. Plants dead; all the aphids dead.

Plant No. 21. *Shirley Poppies.*

4. 6. 13. Infected from Euonymus tree growing in Acton Lodge garden with four w. v. ♀'s.
18. 6. 13. Several apterous forms present beneath the leaves.
28. 6. 13. Several colonies present on the stem and leaves, along the mid-ribs; aphids big and healthy.
30. 6. 13. Aphids fairly numerous, along flower-stalks and beneath the leaves.
12. 7. 13. Winged viviparous females produced.
14. 7. 13. Many winged forms produced; Poppies in flower; several colonies going well.
20. 7. 13. Infestation moderate; aphids dying off; plants sickly.
21. 7. 13. Poppies looking very sickly; aphids nearly all dead. The soil used was poor and plants did not do well.
28. 7. 13. Plants dead.

Plant No. 22. *Onions.*

13. 6. 13. Infected from Rumex No. 1 with eight w. v. ♀'s.
28. 6. 13. No aphids present; have died off.

Plant No. 23. *Red Beet.*

13. 6. 13. Infected from Rumex No. 1 with eight w. v. ♀'s. These plants were grown in the open garden, and at the time of infection were covered with a muslin cage. Although I searched carefully and found no aphids on the plants, one could not be absolutely certain that some individuals from the neighbouring infected Beans had not infected them. The plants in the pots did not, generally speaking, grow as healthily as those in the open garden, and I wanted to see the effect on these plants which were growing well. Soon after infecting them the winged forms made their way up to the top of the muslin bag, but a day or so after they seemed to settle on the plants.

28. 6. 13. A few colonies present on the underside of some of the leaves.

28. 7. 13. Several colonies present beneath the leaves; nymphs of winged viviparous females present; some of the leaves are crinkled along the veins showing a slight damage due to the aphids; there are however not very many aphids produced, and the infestation is only moderate.

Plant No. 24. *Onions.*

18. 6. 13. Infected from Euonymus tree growing in Acton Lodge garden with four w. v. ♀'s.

28. 6. 13. Aphids all dead.

Experiments. Series B.

In this series of experiments, the writer wished to find out if the winged migrants from Euonymus showed any preference for particular plants, if a choice of food plants were given.

It was desirable that the aphids should, as far as possible, be under natural conditions. At the same time it was necessary to ensure against infection from other plants, and that the plants should be grown under conditions which enabled constant observations to be made.

For these reasons, a wooden framework, 33 feet long, 6 feet wide, and 5 feet 6 inches high, was erected over a plot of ground in Acton Lodge garden. This was covered with very fine muslin which was carefully fastened down to the woodwork so that insects could not get in or out. The tent was divided into three compartments by muslin partitions, so that the insects could not pass from one compartment to the other.

Early in April the plot of ground surrounded by the tent was heavily fumigated with carbon di-sulphide. At the end of this month several food plants which had been raised in pots from seed were placed in the tent, and in addition, some seeds of Broad Beans, Shirley Poppies, Mangolds, etc. were sown.

In Compartment *A*, the following plants were grown: Broad Beans, Shirley Poppies, *Papaver rhoea*, Mangolds, Red Beet, Sugar Beet, Swedes, Onions, *Rumex sanguineus*, Nasturtiums.

In Compartment *B*, Broad Beans, Shirley Poppies and *Papaver rhoea*.

In Compartment *C*, Broad Beans and *Rumex sanguineus*.

Each compartment was entered by a door which opened from outside into each compartment separately.

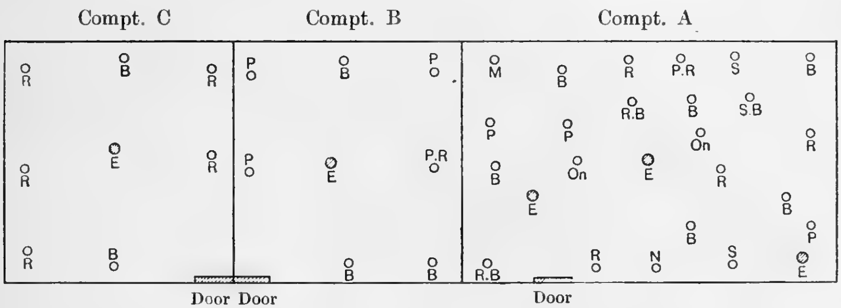
At the beginning of June (3. 6. 13), Euonymus bushes which had been infected in May with *Aphis rumicis* from the Euonymus bush *B*,

referred to in series *A*, were placed in the tent. These bushes had been kept covered with muslin, and although the number of aphids produced on the bushes by this date was very few, several healthy colonies were present on them. The plants in the tent were carefully examined before the infected bushes were introduced, and were found to be quite free from aphids. They were very clean and healthy, and owing partly to shade afforded by the muslin, and partly to the effect of the fumigation, they were making splendid growth.

Owing to the colony of Aphids on the Euonymus bush placed in the Compartment *C* not developing, no infestation of *A. rumicis* occurred in this compartment, consequently no results were obtained.

After the Euonymus bushes were placed in the tent, the plants were kept under close observation and notes made from time to time. These notes are given below, with the dates when the observations were made. They show the results obtained, and indicate the progress of the infestation of the different plants by the winged migrants from the Euonymus bushes.

The following plan shows the arrangement of the food plants in the different compartments.



General plan indicating the general arrangement of the food plants in the tent.

P. = Shirley Poppies; *B.* = Broad Beans; *R.B.* = Red Beet; *S.B.* = Sugar Beet; *E.* = infected Euonymus bush; *M.* = Mangolds; *S.* = Swedes; *R.* = *Rumex sanguineus*; *N.* = Nasturtiums; *P.R.* = *Papaver rhoea*; *On.* = Onions.

Compartment A.

3. 6. 13. Euonymus bushes infected from Euonymus *A*, placed in the tent.

28. 6. 13. Some winged viviparous females have now migrated from the Euonymus to Broad Beans, and a few colonies of lice are produced on these plants.

3. 7. 13. Aphids now infesting the Broad Beans in fair numbers, and many colonies are present on the flower-stalks and tips of the young shoots.

A few small isolated colonies present on the veins beneath the leaves of the Rumex plants, but very few in numbers. One Rumex plant which is producing a tall flowering head has a number of colonies on it.

The other plants not infected.

14. 7. 13. The aphids are heavily infesting the Broad Beans, and appear to have all left the Euonymus bushes.

A few isolated, small colonies on the Rumex leaves. I found one winged viviparous female on the Poppies, but no colonies forming yet on these plants.

Many winged viviparous females are produced, and a number are walking on the roof of the tent as though wanting to escape.

A few aphids present on the leaves of the Red Beet, but numbers very few.

Other plants not infected.

22. 7. 13. The Broad Beans are very heavily infested, although some of the plants still have plenty of young growth to afford food for the aphids. Many of the young pods are heavily infested with the aphids, and the colonies have extended to about half-way down the stems in some cases. Many colonies also beneath the leaves, and the winged females present on these plants chiefly settle below the leaves, although several are also on the stem.

A few colonies are now forming on the Poppies being chiefly collected along the flower-stalks, but some also on the stems and beneath the leaves.

There are a few colonies on the Red Beet and Sugar Beet, but very few in number. Some of the Red Beet leaves are crinkled along the veins, which seems to be due to the action of the aphids.

Several of the Rumex plants have a few colonies, consisting of a small number of individuals, present on the underside of the leaves.

I found one or two small colonies of apterous forms present on the Euonymus bush, but the aphids seem to have practically all left these plants.

There are no aphids on the Swedes, Nasturtiums and Onions.

10. 8. 13. The Broad Beans in many cases are almost smothered with aphids, the underside of many of the leaves being almost covered with them. They are also in great numbers on the young pods. The terminal shoots of these plants are brownish in colour and dying off.

The Shirley Poppies are now fairly heavily infested, and there are many winged viviparous females and nymphs on them. The aphids are to a great extent collected along the flower-stalks, towards the flower-heads, but also some along the stems and beneath the leaves. There are several colonies also present on the *Papaver rhoea* plants.

There are a few isolated colonies, small in number, present on the Red Beet and Sugar Beet; and a very few aphids on the Mangolds, but in this latter case only a small isolated colony on a very few leaves.

Several small colonies present beneath the leaves of the *Rumex sanguineus* plants. There is a great deal of Rumex present so that the colonies are widely distributed.

There are no colonies forming on the Swedes.

10. 10. 13. The Broad Beans, Poppies, and Nasturtiums have all died down. Beet, Mangolds and Swedes are growing well, and look healthy. Aphids seem to have all disappeared, having died off, and only an isolated individual to be seen here and there.

Compartment B.

3. 6. 13. Euonymus bush infected with *Aphis rumicis* from Euonymus *B* placed in this compartment.

3. 7. 13. Winged viviparous females have been produced on the infected Euonymus bush, and several winged forms have migrated to the Broad Beans where they are forming colonies.

14. 7. 13. Broad Beans now fairly heavily infested, and a few small colonies are also going on the Poppies.

22. 7. 13. The Broad Beans are heavily infested. Colonies forming rapidly on the Shirley Poppies. The aphids have all left the Euonymus bush.

10. 8. 13. The Broad Beans and Shirley Poppies are now heavily infested. *Papaver rhoea* plants also attacked, and many of the leaves are curled and clustered together owing to the aphids. The Shirley Poppies are especially infested along the flower-stalks.

10. 10. 13. The Poppies and Beans have now died down. The aphids seem to have all disappeared, having died off. An isolated winged form here and there on the dead plants. No aphids on the Euonymus bush, which is growing fast.

Compartment C.

3. 6. 13. Euonymus bush infected with *Aphis rumicis* from Euonymus *B*, placed in this compartment.

The colony is very small, and does not seem to be making any progress.

3. 7. 13. One small colony on the Rumex plants. The aphids on the Euonymus bush are small in size and numbers, and do not appear to be going well.

14. 7. 13. No aphids on the Broad Beans. The aphids present on the Euonymus bush are not making any progress.

10. 8. 13. No aphids on the Euonymus bush. A few winged viviparous females present on the Broad Beans, but only a few small colonies formed.

10. 10. 13. The Broad Beans have died down.

Experiments. Series C.

This series of experiments consists of observations made on plants grown in the open garden at Acton Lodge. Many different kinds of plants and vegetables were cultivated in various parts of the garden, and weeds were also allowed to flourish in order that observations might be made on the migration of the winged forms of *Aphis rumicis* from Euonymus.

On May 24th, three small Euonymus bushes found near Richmond, heavily infested with *Aphis rumicis* (*euonymi*), were introduced into the garden at Acton Lodge. There were great numbers of winged forms on these bushes at this time.

The following notes recorded below will show how the aphids became distributed to many of the plants growing in the garden. The dates given do not denote the exact date when the plants became infected, but the date on which the observations were made. It may be noted, however, that in the case of the Broad Beans, *Aphis rumicis* was not found on these plants until the date given below. The infestation of these plants occurring so quickly after the introduction of the infected Euonymus bushes (one bush was placed close to a row of Broad Beans) leaves little doubt that the infection came from Euonymus. By the middle of June, practically all the aphids had left the infected Euonymus bushes.

Date	Host Plant	Remarks
24. 5. 13.	*Euonymus europaeus* ..	Three bushes heavily infested with *Aphis rumicis*, introduced into Acton Lodge garden; many winged viviparous females present. These had all migrated by the 30th May, and by the middle of June the bushes were quite free from aphids.
25. 5. 13.	Broad Beans	Many winged females present and several colonies forming.
29. 5. 13.	Broad Beans	Many colonies now developing on these plants.
29. 5. 13.	*Euonymus europaeus*	Found several winged viviparous females on some large Euonymus bushes in Acton Lodge garden, and colonies are being produced on these bushes.
1. 6. 13.	Spinach	Several plants infected and colonies forming on them, along the stems and flower-heads.
1. 6. 13.	Parsnips	Some old Parsnip plants which are running to seed are now infected, and colonies forming in the flower-heads.
2. 6. 13.	*Rumex*, sp.	Several plants now infected, one plant near the Broad Beans being especially heavily infected.

13. 6. 13.	Scarlet Runner Beans	*Aphis rumicis* forming colonies on the tips of the young shoots, and a few colonies beneath the young leaves.
13. 6. 13.	Spinach.	A few plants near the infested Broad Beans are now fairly heavily infested.
13. 6. 13.	Red Beet	A plot of Red Beet plants near the Broad Beans have now several colonies on them, and some of the leaves are crinkled along the veins which is probably due to the presence of the aphis. The colonies are forming along the veins beneath the leaves, but only a few leaves infected. Another plot of Red Beet at some distance from the Broad Beans is not infected.
13. 6. 13.	Onions	A few individuals are present on a few plants; they seem to wander to the top of the leaves. Found a few lice produced on these plants, but in a few days the aphids disappeared from the plants.
23. 6. 13.	Red Beet	Several plants infected. The aphids have collected chiefly on the very young leaves, near the base of the mid-rib, and along the veins. These plants are however only slightly infected.
23. 6. 13.	SugarBeet	Only a few aphids present on these plants.
23. 6. 13.	Mangolds	A very few leaves with one or two small colonies present.
23. 6. 13.	*Atriplex hortense* ..	These plants are now growing tall, and several colonies of aphids are present along the young parts of the stems.
3. 7. 13.	Peas	A few small colonies present on the young terminal shoots.
3. 7. 13.	*Carduus* sp.	A few of the plants in a large plot of thistles are heavily infested along the stems.
3. 7. 13.	Tomatoes	A few individuals generally distributed over these plants, but the aphids do not seem to be forming colonies.
3. 7. 13.	Scarlet Runner Beans	Several plants fairly heavily infected, the aphids forming colonies on the young terminal shoots, and some along the mid-ribs beneath the leaves. There are several small colonies present on the leaves of the Dwarf French Beans.
4. 7. 13.	Asparagus	These plants have now grown big and bushy, and many colonies of *Aphis rumicis* are present on them; nymphs of winged females are produced.
4. 7. 13.	*Capsella bursa-pastoris*	Several Shepherd's purse plants are infected, the colonies forming along the apex of the stems at the base of the flower-stalks.
4. 7. 13.	*Chenopodium album* ..	There are many small Chenopodium plants fairly heavily infested. The colonies are present chiefly along the veins of the leaves, which make the leaves curl. Several nymphs of winged females produced.

4. 7. 13.	*Urtica* sp.	A small species of nettle, about a foot high, is infected. The colonies are forming along the apex of the stem and along the mid-rib of the leaves, causing the terminal leaves to cluster together; nymphs of winged females are present.
4. 7. 13.	Dahlias	One Dahlia plant has two or three large colonies of big apterous females on it. The aphids are collected along the flower-stalks, towards the base of the flowers.
18. 8. 13.	Nasturtiums	These plants are growing beneath the Dahlias. The aphids have now left the latter plants, and there are several colonies present on the Nasturtiums.
— 9. 13.	*Chenopodium* sp. ..	A few of these plants are still infested with aphids.
— 9. 13.	*Urtica* sp.	A few aphids still present on these plants.

General Conclusions.

The general results obtained in these experiments have already been indicated in the notes given about the various plants.

It is seen that, in the experiments, series *A*, as the different generations of winged migrants were produced they were transferred to different host plants. It was thought the previous plant host upon which the aphids were produced might have an influence on the degree of infestation of the succeeding host plants to which the winged migrants were transferred. The results obtained do not, however, give sufficient evidence of this. It will be necessary to carry out this experiment with a large number of plants, the number of aphids produced on the different plants in a specified period of time being counted. Further, it will be necessary to find the variation in the number of aphids produced on different plants of the same species, for the purpose of comparison, before definite conclusions can be drawn.

The Euonymus bush *A* (series *A*) became heavily infested with *Aphis euonymi* in February by the rapid reproduction of the original small colony. The bush had been put into the greenhouse and the sheltered conditions no doubt favoured this rapid reproduction.

The Euonymus bush *B* which was infected with winged viviparous females from *A* did not become heavily infested until several weeks had elapsed, although by the middle of May it was almost smothered with the aphids.

The third set of Euonymus bushes which were infected from Euonymus *B* early in May had only a few small colonies on them by the beginning of June. On the third of this month they were placed in the muslin tent and although winged forms were produced towards

the end of June the numbers of aphids produced on these bushes were very small. In fact the colony on the Euonymus bush placed in the compartment *C* of the tent made little or no progress, so that results were not obtained for this compartment.

Now if we compare these results with what happened in the tent when the winged migrants settled on the Broad Beans, we find that in two or three weeks these latter plants became very heavily infested by the rapid reproduction of the aphids feeding on them.

Also in series *A* the Rumex plants, Broad Beans, and Poppies infected from Euonymus *B* with winged viviparous females became heavily infested in a few weeks.

The plants in series *A* were all infected with winged viviparous females, with the exception of Rumex No. 2, which was infected with apterous viviparous females. Winged forms were used because it is the winged migrants which infect new host plants. It will be seen, however, that the apterous viviparous females from Euonymus flourished and reproduced in great numbers when transferred to *Rumex sanguineus*, winged migrants being produced in due course.

A noticeable feature throughout the experiments was the migratory tendency of the winged viviparous females. Soon after the winged generation was produced on the various plants, the winged forms showed a desire to migrate and collected in vast numbers at the top of the muslin bags which covered the plants. They seemed active and restless, and apparently not feeding on the host plant on which they were produced. However, many undoubtedly produced "lice" on the host plant, and several could usually be found sitting beneath the leaves, but the majority of the winged forms crowded round the top of the muslin cover, even when the host plant was still in a healthy condition. When the top of the cover was opened they immediately took flight.

It would appear from these observations that the winged females demand a change of host plant, and it is for this reason that certain plants which may be heavily infested early in the summer suddenly become free from aphides, owing to the production of winged migrants which, when they are produced, tend to leave the original host plant. In the case of *Aphis euonymi* I found hundreds of young nursery Euonymus bushes smothered with these aphids in May, whereas a few weeks later the bushes were almost free from them. Two or three of these bushes were kept under close observation. On May 23rd, they were heavily infested with *Aphis euonymi*, many winged forms being present. A week or so later the bushes were almost free from these aphids, and

the winged migrants had gone to Broad Beans, on which plant they were reproducing rapidly.

This brings us to the important question, What are the factors underlying the production of winged forms and the consequent migratory habits of Aphides? The migratory instincts of the winged females may underly the desire to escape from the original host plant, but it may be that a change in the constitution of the cell sap of the host plant, which affords the food of Aphides, has an influence on the production of winged forms and the consequent migration of the Aphides from the original host plant.

In the case of the Euonymus bushes *A* and *B* (series *A*), when these bushes became very heavily infested, being practically smothered with aphids, both the winged viviparous females and the apterous forms became surprisingly active and ran over the bushes and muslin cover in a most restless manner as though wishing to escape. Moreover, they became considerably reduced in size, both apterous and winged forms being very much smaller than those produced on the Broad Beans and Rumex plants. In the latter stages of the heavy infestation of the Broad Bean plants, the aphids on these plants were also much smaller than in the early stages of infection. It may be that owing to the pathological condition of the plants induced by the heavy infestation, the aphids were unable to obtain sufficient food, but there is the fourth question of the change in the constitution of the cell sap brought about by the heavy infestation of the plants.

Woodworth, C. W. (1908)[1], who made some observations on *Aphis brassicae*, states that when a plant wilts the birth rate decreases and suggests that the failure of plant lice to develop winged forms under favourable conditions is due to the rapid development of the rest of the body. He refers to a paper by Clark in the *Journal of Technology*, Vol. I (which, unfortunately, I have been unable to consult), who obtained winged forms of *Macrosiphum rosae* in the first generation, by rearing the aphids on rose-cuttings grown in sand wetted with a solution of magnesium salts.

During the summer of 1913, I carried out a number of experiments with *Macrosiphum rosae*, on rose-trees grown in soil treated with definite quantities of various inorganic salts. I regret that owing to the extraordinary numbers of aphids that were produced, and the confusion resulting from this, that the experimental error is too great to allow

[1] Woodworth, C. W. (1908), *Entom. News*, Philad. 1908, XIX, pp. 122–3.

of conclusions being drawn from them. It is intended to repeat these experiments, making the necessary alterations to avoid error.

During the summer of 1911 a young apple tree infected with *Schizoneura lanigera* Hausm. was kept under observation in a greenhouse. The aphids reproduced in great numbers, the leaves began to wilt, and the tree looked very sickly. In the later stages of the attack, winged viviparous females were produced in vast numbers, and most of them left the tree and collected on the woodwork of the greenhouse. Later, all the leaves on the plant died, and although there were several " living " branches the aphids practically all died off.

The winged forms of *Schizoneura lanigera* are not common in England, and it would seem that the heavy infestation produced some change in the constitution of the cell sap, which induced the production of winged migrants. When a plant becomes so heavily infested that the leaves begin to wilt and the green parts are smothered with aphids, the normal green surface of the plant which carries on the processes of photosynthesis is considerably reduced in area and as a result the constitution of the cell sap is probably changed.

It is a well-known observation that aphids prefer the young growing shoots of the plants they attack. They readily select the parts of the plant which afford the best supply of sap.

In early summer, rose-trees frequently become infected with *Macrosiphum rosae*, the aphids collecting on the young stems and terminal shoots, where they reproduce in great numbers. Later on in the season, the trees are often quite free from these aphids.

During the summer of 1913, one rose-tree in Acton Lodge garden was kept covered with a muslin cage. The tree was covered early in the summer and infected with *Macrosiphum rosae*. The colonies increased in great numbers on the young terminal shoots, and along the petioles of the flower buds, and soon the plant became very heavily infested, vast numbers of winged forms being produced. Many of the leaves died and the young terminal shoots looked very sickly. Later on practically all the aphids died off. The tree then began to make new growth later in the summer. These young shoots soon became infected and the aphids reproduced in great numbers on them.

It was noted in the case of the rose-tree experiments mentioned above, that at first the aphids collected on the young terminal shoots, or along the petioles of the flowers, just beneath the buds. When the flower buds were cut off, the aphids very soon left the petioles and went to another part of the plant. Gradually as the numbers

increased, they distributed themselves beneath the leaves, along the mid-ribs, and secondary veins, and, finally, practically the whole plant in many cases became smothered with the insects. At this stage, both the apterous and viviparous forms became active and restless and ran over the plant as though wishing to escape. Many of them left the plants and died on the soil in the pots.

From these observations, it would appear that at different periods of the growth of plants, a change in the quality or constitution of the cell sap occurs which renders it unsuitable for the aphids. Further, the pathological condition of the plants, induced by heavy infestation, no doubt causes considerable changes in the constitution of the cell sap.

When Broad Beans are infected with *Aphis rumicis*, the young terminal shoots are first infested, the aphid colonies gradually extending down the stem, and on the veins below the young leaves.

From an examination of sections through the stems and leaves of some plants, which were infested with aphids, one sees that the stylets are forced through the epidermis and pass intracellularly between the cells of the plant tissues towards the phloem cells of the vascular bundles. The stylets often pass in a very irregular manner between the cells of the cortex, and are not forced into the plant in a direct straight line.

From a recent study of the mouth parts and mechanism of suction in *Schizoneura lanigera*, which the author has recently carried out, it has been shown that the plant juices pass up to the pharynx through a very minute suction canal formed by the partial fusion of the two internal stylets[1]. This canal is extremely minute in transverse section, and it is highly probable that the ascent of the sap through it is largely due to capillarity.

This is an important point for consideration. It is obvious if the surface tension of the cell sap is such that it cannot ascend up the minute capillary tube the aphids would be unable to obtain food. It is probable that in young growing shoots the stylets can be more easily forced into the plant tissues, but there is the question of the difference in the supply and constitution of the cell sap in young, actively growing parts of a plant. It is not improbable that in the case of small plants heavily infested with aphids, the cell sap is rendered toxic, or at any rate distasteful to the insects.

I have indicated that the individuals living on a plant very heavily infested with aphids become gradually smaller, and apparently derive

[1] This paper will shortly appear in the *Transactions of the Linnean Society*.

no nourishment from the host plant. This was seen in the case of the aphids on Euonymus, and on Broad Beans. It would be interesting to know if the pathological condition of the plants had an effect on the surface tension of the cell sap.

In the paper on the mouth parts of *Schizoneura lanigera*, referred to on the preceding page, there is described a " taste organ," which is situated near the entrance of the suction canal into the pharynx. It is very probable that by means of this organ the aphids are able to appreciate changes in the quality of the cell sap, although owing to the extreme minuteness of these mouth parts it is almost impossible to demonstrate its function practically. That the aphids become restless and dissatisfied with their hosts at different periods of the plant's growth, or when the plant is heavily infested, has been seen throughout these experiments as is indicated in the observations given.

As is seen in the case of the tent experiments, *Aphis rumicis*, under favourable circumstances, will select its host plant. Thus in the Compartment *A*, Broad Beans became first infected, then the Shirley Poppies and the other plants only became infected to a very slight degree.

Davis (1909), found that *Aphis maidis* Fetch, showed a decided preference for broom corn plants over Indian corn and Sorghum[1].

It is an interesting feature of aphid habits, that one species may infest a number of different species of plants. This is the case with the species at present under consideration (*Aphis rumicis*). It is readily seen, however, that although this particular species of Aphis may live on a number of different species of plants, some of these plants are subject to a greater infestation than others.

It was observed that while Broad Beans infected with *Aphis euonymi* from *Euonymus europaeus* became rapidly infested by the reproduction of the aphids, Red Beet infected from Broad Beans did not become so heavily infested, although the few aphids produced appeared to be healthy.

Again, in all cases where Broad Beans and Shirley Poppies were infected with this species, the former plants became heavily infested sooner than the latter.

Further, it was noted that certain plants in the garden of Acton Lodge were infected with *Aphis rumicis*. On many plants, such as Broad Beans, *Rumex* sp. and *Chenopodium album*, the colonies reproduced in great numbers and in most cases gave rise to a more or less

[1] Davis, J. J. (1909), " Biological studies of three species of Aphididae," *U.S.D.A. Bur. Ent.* Techn. Ser. No. 12, pt. VIII, p. 146.

heavy infestation. On many other plants, however, although aphids were present, the colonies were small. The individuals looked healthy and happy, but the numbers produced were small, and the plants really never became heavily infested.

This would seem to show that the cell sap of certain plants affords a suitable stimulus for certain species of aphids, resulting in rapid reproduction of young, while on some other plants, although the cell sap may afford a suitable food for the specific aphids, the stimulus derived from it does not induce such a rapid reproduction of young.

There is the question that the quality of the sap in any particular species of plant may be subject to change according to the soil conditions in which it may be growing. I have not any particular reference to hand, but I believe work has been done, showing that by treating certain plants with chemical substances they may be rendered immune to a specific fungus attack. Mangolds and Beet have been recorded from time to time, both in this country and in France and Germany, as subject to infestation by *Aphis rumicis.* In some seasons, on the other hand, these plants may be more or less free from infestation.

In connection with this point, there seem to be two points for consideration. Firstly, whether the presence in the neighbourhood of these crops of food plants for which *Aphis rumicis* shows preference, afforded sufficient food for the aphids and so prevented an overflow to the Mangolds and Beet. Secondly, whether any special manurial treatment of the soil rendered the crop more susceptible to attack.

It would be interesting during such an outbreak, to tabulate the food plants found in the immediate neighbourhood. It does not seem at all unfeasible that in a very bad season, a " catch crop " might be sown; for example with *Aphis rumicis,* the aphids evidently prefer Broad Beans and Poppies if these plants are present.

Malanquin and Moitié (1913)[1] record heavy attacks of *Aphis papaveris* in 1911 on the Sugar and Cattle Beet in the North of France. They record the presence of the Aphis also on Spinach, Rhubarb, Poppies and Beans. These authors add that this Aphis leaves the seed plants about the middle of July because they do not afford sufficient food and go to the Sugar and Cattle Beet.

Davis (*op. cit.* p. 132) observed with *Aphis maidi-radicis* that when food supply was scarce, the tendency was for winged forms to be produced.

[1] Malanquin, A. and Moitié, A. (1913), " Le Puceron de la betterave dans le nord de la France," *La Vie Agricole,* II, No. 24, pp. 696–699.

Throughout my experiments it was observed that, when the plant had finished its young active growth, or became heavily infested with aphids, the changes resulting either in the quality or quantity of the cell sap (or both) seemed to induce the production of winged forms, which wanted to migrate to other plants.

It may be that in the case of the Compartment *A* in the tent, the Shirley Poppies and Broad Beans afforded sufficient food, and thus the Mangolds and Beet did not become heavily infested.

Gaumont (1913)[1] records a heavy infestation of Beet by *Aphis euonymi* in the South of France during 1911.

Theobald (1912, p. 471, *op. cit.*) records migration flights of *Aphis rumicis* in the South of England during 1911. Poppies became very heavily infested, and then when these became "seedy," masses of winged migrants were distributed over many different plants, but only on Dahlias, Beet, and Mangolds did they flourish to any great extent.

It would seem that under natural conditions winged migrants of *Aphis rumicis* are produced on the host plant, and they take flight, being carried partly by their own powers of flight, partly by the wind, to many different species of plants. On some plants such as with Onions in these experiments, they soon die off, on others they live happily, and form small colonies, while on others they reproduce in enormous numbers and heavily infest the plants. In the latter case, it would appear that the cell sap is best suited for the particular species of Aphis and affords the necessary stimulus for the rapid reproduction of young.

It remains yet to be proved whether the stimulus derived from the cell sap of the previous host plant has any influence on the degree of infestation of the succeeding host plant.

Some seasons are much more favourable than others for the distribution of aphids. The present season of 1913 has been a particularly favourable one for Aphis "blight[2]." Winged aphids are very fragile, and, if the weather conditions are wet and severe, the winged migrants are unable to withstand the journeys from plant to plant.

In favourable seasons the distribution of aphids over a district from plant to plant may be very extensive.

[1] Gaumont, L. (1913), "Le Puceron de la betterave," *Revue de Phytopathologie*, I, No. 1, April 20th, 1913, pp. 12–13.

[2] *Gardeners' Chronicle*, London, 7th June, 1913, p. 377.

SOME OBSERVATIONS ON THE LIFE-HISTORY AND BIONOMICS OF THE KNAPWEED GALL-FLY *UROPHORA SOLSTITIALIS* LINN.

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(With Plates XI and XII and 1 Text-figure.)

CONTENTS.

Introduction.

In September 1911, whilst collecting seeds of wild plants at Prestatyn, North Wales, I found galls in many of the flower-heads of the small knapweed, *Centaurea nigra* L., and these on further examination were found to contain dipterous larvae.

On counting the seeds contained in a few of the galled flower-heads, and comparing the numbers obtained with the numbers present in ungalled heads, it was seen that considerably fewer seeds were present in the former than in the latter It therefore seemed probable that

the dipterous larvae present in the flower-heads, by inducing gall-formation, caused a reduction in the number of the seeds normally produced by this troublesome and useless weed, which is very common in many pastures and meadows.

A number of the infected heads were brought to Manchester, and kept until the following spring, when, towards the end of June, imagines commenced to emerge from the galls, and continued to do so during the ensuing three weeks.

The fly was recognised as a Trypetid and specimens for determination were submitted to Mr J. E. Collin, of Newmarket, to whom I am indebted for naming them; they belong to one of the common species of Trypetidae, viz. *Urophora solstitialis* L. Mr Collin also informed me that so far as he knew the larvae and pupae of this species had never been scientifically described.

Early in July some young flower-heads of the knapweed were gathered and a few fertilised female flies were placed on them in a covered glass jar. The females deposited eggs freely, and in eight days from the date of oviposition free larvae were observed within the flower-heads. It was thus apparent that the flies would breed freely in captivity, and Professor Hickson suggested that I might undertake a study of the life-history of this species.

The work was carried out in the Department of Agricultural Entomology of the Victoria University, Manchester, and I wish here to thank Professor S. J. Hickson for his kindness in providing me with opportunities by which I have been enabled to undertake this research; to Dr A. D. Imms my thanks are also due for valuable suggestions and advice given during the later stages of its progress, and to Professor F. E. Weiss for permission to use apparatus belonging to the Botanical Department. My indebtedness to others who have assisted me in various ways, is acknowledged in the text.

Description of fly and classification.

The fly was described by Linnaeus (1758) under the name *Musca solstitialis*; since then it has been frequently referred to and more fully described, under various names, by several entomologists. Loew (1844) discussed the characteristics of this species very fully, and he recognised and described five well marked size and colour varieties. In his monograph *Die europaischen Bohrfliegen* (1862) the same author gives a full description of the species, together with the synonomy;

the description given by Schiner (1864) is more complete however, and of this the following is a slightly abbreviated translation.

"Wings yellowish-white, with brown bands, of these the first and second are always widely separated at the anterior border. Body glossy black; thorax with a brownish-yellow dusted appearance, and with the usual yellow side-stripes as in *Ur. stigma*; scutellum yellow, blackish at the sides. Ovipositor much longer than the abdomen, and swollen from the base to the middle. Head yellow, posterior aspect black or brown; facial aspect paler, frons distinctly brighter in the centre, sometimes rusty-yellow. Antennae, proboscis, and palps, reddish-yellow; proboscis lobes rather narrow, and much elbowed backwards. Legs yellow, in most specimens the anterior femur with a black stripe on the outer border, less frequently a similar stripe is present on the mid and hind femora; terminal tarsal joints brown. Wings with a yellowish-white tinge; at the base and towards the anterior border as far as the stigma, a deeper yellow, with four lighter or darker brown moderately straight cross bands. The first lies near the wing base, is frequently indistinct, and reduced, but always present; it extends backwards at the most into the anal cell, and is always widely separated from the second band. The second proceeds from the point of the brownish-yellow stigma over the discal cross-vein, almost completely straight to the posterior wing-border; the third arises at the anterior wing-border in front of the apex of the marginal cell and proceeds moderately straight over the posterior cross-vein to the posterior wing-border; the fourth is usually narrowly continuous with the third anteriorly, and borders the wing-tip just beyond the fourth longitudinal vein. The clear area between the second and third bands is at least double the width, or frequently only just wider than, the bands themselves. Examples are found in which the bands are very much faded, their position, however, is always distinctly recognisable. Discal cross-vein a little beyond the middle of the discal-cell; 3·1—6·2 mm."

Bezzi (1910, 1913) has recently proposed that the family name should be Trypaneidae instead of Trypetidae, by which name this family of acalypterate flies has been known so long. He divides the family into two sub-families, the Dacinae and the Trypaneinae; the latter is divided into three tribes, Ceratitininae, Myiopitininae, Trypaneininae. The second tribe contains only three genera: *Myiopites* (*Stylia*), *Asimoneura*, and *Urophora*.

Among other characteristics of the tribe Myiopitininae are the

following: "the species are found exclusively in temperate countries, being wanting in the tropics; the larvae live only on plants of the family Compositae, and often make galls" (Bezzi).

The genus *Urophora* was proposed by Robineau-Desvoidy in 1830, one of many that he formed out of the large genus *Trypeta* of Meigen, and from this date onwards the name of the species *Urophora solstitialis* Linn., has been accepted by most entomologists.

The following is a list of the principal synonyms of the species as given in Loew's monograph.

Urophora solstitialis Linn. (1758) ♂ and ♀.

Musca solstitialis Linnaeus, Syst. Nat. x. 601, 98. Faun. Suec. ii. 1879. Syst. Nat. xii. 999, 127.
Musca Dauci Fabricius, Mant. Ins. ii. 353, 118. Ent. Syst. iv. 358, 187.
Musca solstitialis Cederhjelm, Prod. 318, 1006.
Dacus Dauci Fabricius, Syst. Antl. 277, 22.
Dacus hastatus Fabricius, Syst. Antl. 276, 15.
Trupanea Leucacanthi Schrank, Faun. (Boic.) iii. 141, 2507.
Tephritis solstitialis Fallen, Ortal. 6, 5.
Trypeta solstitialis Meigen, Syst. Beschr. v. 324.
Trypeta pugionata Meigen, Syst. Beschr. 330.
Urophora solstitialis Walker, Ent. Mag. iii. 7 (ex parte) Macquart, Suit. Dipt. ii. 457, 9.
Trypeta solstitialis Loew, Germ. Zeitschr. v. 355.

Geographical distribution.

Urophora solstitialis has been recorded from nearly all the countries of Europe; a list of these records is given by Schiner (1858). Mr J. E. Collin informs me that it is common and widely distributed in England; Fitch (1872) records it from Suffolk; Wingate (1906) from Hesleden, Durham; Connold (1901) from Hastings, Sussex. I have collected the galled flower-heads containing larvae of this species at Prestatyn, North Wales, and also at Port Erin, Isle of Man; and Dr A. D. Imms collected a few galled-heads at Llwyngwril, Merionethshire. Professor J. W. H. Trail of Aberdeen very kindly sent me the following list of localities in Scotland where galled heads containing the larvae have been obtained: Aberdeenshire and Kincardineshire, especially in the valley of the Dee; near Dunkeld and elsewhere in the valley of the Tay, from Glen Falloch, and from Loch Lomond in Perthshire; in these and in other localities the galls are abundant. I am indebted to Professor G. H. Carpenter of Dublin for a note on its occurrence in Ireland;

it has been recorded from Ballyvaughan, Co. Clare; Westport, Louisburgh and Clare Island, Co. Mayo. Professor Carpenter further remarks that probably the species is widely spread in Ireland.

It is worthy of note that specimens belonging to the genus *Urophora* have been recorded only from the old world. In the *Katalog der Paläarktischen Dipteren* (1905) twenty-nine species of this genus are recorded from Europe and Northern Africa; seven of these are listed as British (Verrall) and one species, *U. spoliata* Hal., has not been found elsewhere.

Historical.

Records of detailed observations on the life-history of this species appear to be very scanty, although a few well-known entomologists have studied closely allied forms. Thus Goureau (1845) described the larva and pupa of *U. cuspidata* Meig., and Dufour (1857) those of *U. quadrifasciata* Meig. Until comparatively recently the former was regarded as synonymous with *U. solstitialis* (Schiner, H. Loew); Becker (1902) however, who examined Meigen's type of *U. cuspidata* in the Paris Museum, considers that *U. cuspidata* Meig. is distinct from *U. solstitialis* L. The most complete account of the larva and pupa of a species of the genus *Urophora* was given by Mik (1897) who described those of *U. cardui* L.; the larvae of this species induce galls on the stems of *Cirsium arvense* L.

Boie (1848) obtained *U. solstitialis* in hundreds from galled flower-heads of *Carduus crispus* L.; they emerged from June 8 to July 12. From several thousand pupae only three or four flies emerged in autumn, and his opinion was that this species gave rise to a single brood only, unless exceptional conditions prevailed.

In a paper devoted to the natural history of the Trypetidae, Frauenfeld (1857) refers to this species among others; he states further, that it produces swellings in the receptacles of all the plants that it infects, and he gives a list of its food-plants.

There is a brief paragraph by Kaltenbach (1874) on this species, he gives the names of three hymenopterous parasites reared by Goureau from *U. cuspidata*, as parasites of *U. solstitialis*. He assumed, however, that the two latter were one and the same species.

Fitch (1872, 1879) refers to it in two short notes; it is also referred to by Connold (1901) and by Swanton (1912). Connold gives a short description of the galls together with photographs of these and of the larva and pupa.

Food-plants.

As regards the food-plants Schiner (1858) remarks that:

"The larvae live in the flower-heads of *Carduus nutans* L., *crispus* L. and *acanthoides* L.; they are also found in those of *Cirsium lanceolatum* L., *Centaurea scabiosa* L. and *montana* L., and on other Cynaroideae"; F. Löw (1866) recorded *Centaurea paniculata* L., as a food-plant of the larvae, and Fitch (1872) recorded this species from galled flower-heads of *Serratula tinctoria* L., collected in Suffolk. In a later paper (1879) this observer remarks that in 1872 he added to the list of [British] gall-making Trypetidae, *Urophora solstitialis* L., "which deforms the ovary of the common knap-weed (*C. nigra*) into a hard, woody, but only tactilely noticeable gall."

This is the first record which I have been able to find of the occurrence of this species on *Centaurea nigra*. Curtis (1860) refers to *U. solstitialis* under the name *Tephritis solstitialis* as being abundant on thistle blossoms during the summer, he does not state, however, that he bred the fly from thistles. Connold (1901) and Swanton (1912) both give *C. nigra* as the food-plant of the larvae of this species; Prof. Trail informs me that in Scotland *C. nigra* alone is known as the food-plant.

It is noteworthy that none of the continental authorities, whose writings I have been able to examine, record *Centaurea nigra* as one of the food-plants of these larvae; on the other hand, with the single exception of Fitch's record of *Serratula tinctoria* referred to above, all the records of its occurrence in this country that I have been able to consult, state that *Centaurea nigra* is the food-plant of the larvae here.

Many of the recorded continental food-plants are equally common in this country, whilst *Centaurea nigra* is common on the continent, and it is worthy of remark that there appears to be this difference in the habits of the larvae here and abroad.

The larvae of a closely related species, *Urophora quadrifasciata*, are recorded as feeding in the flower-heads of *Centaurea nigra* (Loew, Schiner); and according to the account of Dufour (1857) the life-history of this species and the effects produced by the larvae on the host-plant, are very similar to those of *U. solstitialis*.

There was just the possibility therefore, that I might be dealing with this species (*U. quadrifasciata*). Through the kindness of Mr J. E. Collin, I have had the opportunity of examining two continental specimens of *U. quadrifasciata* from Bigot's collection, and there is no doubt that the specimens reared here from *Centaurea nigra* are distinct from

the continental specimens of *U. quadrifasciata* that I examined. Possibly in this country *U. solstitialis* feeds also in the flower-heads of various species of thistles, and its occurrence in these food-plants may have been overlooked.

U. quadrifasciata differs from *U. solstitialis* in the following characters. Its average size is smaller. The thorax appears almost black owing to the very slight yellow powdering (Bestäubung) on the surface; all the femora are black also. The ovipositor is not much longer than the abdomen. The four cross-bands on the wings are very broad, dark, and sharply defined; the first band is united with the second, and the third with the fourth at the anterior border of the wing.

Life-history, description of ovipositor, and method of oviposition.

A supply of galled flower-heads was gathered in September, 1912, and one or more of these were examined from time to time in order to find out when pupation commenced. The first indication of change was observed on April 29th, the following spring; in one gall, two larvae were found whose skins were just hardening and changing to a darker colour. On May 3rd, ten individuals were found in one gall, and in nine of these the puparium was hard and definitely formed, whilst the remaining one was still in the larval state. From this date onward pupae were invariably found and in increasing numbers; the latest date on which I found unchanged larvae was May 29th. On June 1st imagines appeared; we may therefore say that the pupal state lasts from four to five weeks.

From June 1st imagines emerged every day until July 3rd; after this date very few emerged and only at intervals of several days, and the last fly emerged towards the end of July. The period of emergence thus extended seven weeks, but the greatest number of flies emerged during the month of June.

The flower-heads from which the flies were obtained were kept inside a cool room during the winter, and in April they were taken into the warmer laboratory. Outside in the open fields, development would probably be slower and the flies would emerge later. In the open, however, flies are on the wing in mid-June.

The number of males and females that emerged between June 3rd and July 3rd, 1913, was counted in order to ascertain the proportion of the sexes to each other. Between these dates 152 male flies and 130 females was obtained. In the early part of June, many more

males than females emerged, but towards the end of the month, this disproportion in the sexes was decreased. Fitch observed that the males emerged before the females, but he only obtained twelve females and eight males; the numbers he dealt with are therefore very small. If the results obtained above should be confirmed by subsequent countings of greater numbers, they might be explained by supposing that the greater numbers of males produced and their early emergence are provisions for ensuring that as far as possible, all the females shall be fertilised.

Four days after emergence, two pairs of flies were observed in copulation, and another pair copulated five days after they emerged (June 5th and 6th). Probably several days intervene between copulation and oviposition, the exact length of time that elapses between these two acts was not determined.

When the female is ready to oviposit she selects an unopened bud; the bracts of this, however, are just beginning to open. If the flower-bud is suitable for the purpose, she is observed to move over it in various directions; at the same time the ovipositor is frequently protruded and inserted at various points between the bases of the scales; she is evidently selecting a suitable place for the insertion of her ovipositor. As soon as this is found she settles down, her head pointing towards the apex of the bud; the first joint of the ovipositor is then bent almost at a right-angle to the abdomen, and pushed between the bases of the lowest and outermost scales; whilst in this position the ova are placed within the flower-head.

If a flower-head which contains eggs is severed vertically into two halves, and carefully examined, the eggs will be found either in the space between the upper surface of the florets and the overlying bracts (Fig. 2) or between the florets themselves. In order to understand how the eggs are placed in these positions, the ovipositor, during the process of oviposition, may be rapidly severed from the abdomen with a sharp pair of fine scissors, and its position in the flower-head observed; or in a fortunate section of an infected flower-head the tunnel made by the passage of the ovipositor may be seen (Fig. 13). Evidence has been obtained by both these methods, and in order to explain the process of oviposition in a more complete manner, a short description of the ovipositor is inserted here.

The female fly possesses the usual corneous, pointed, three-jointed ovipositor which is characteristic of the three closely related families of acalypterate muscids, Trypetidae, Ortalidae and Lonchaeidae (Bezzi).

The first segment of the ovipositor (which appears as the terminal segment of the abdomen) is about 2·7 mm. long; it is swollen anteriorly, being about 0·6 mm. across in this region, and it becomes narrower in the posterior portion; near the distal end it is about 0·25 mm. in diameter. The walls are strongly chitinised and it is covered with numerous hairs.

The second or middle segment of the ovipositor is about 2·3 mm. in length, by 0·15 mm. wide along its whole length, and consists of a transparent flexible membrane in which a great number of small chitinous sclerites are partially embedded. This segment is capable of protrusion and retraction, like the finger of a glove.

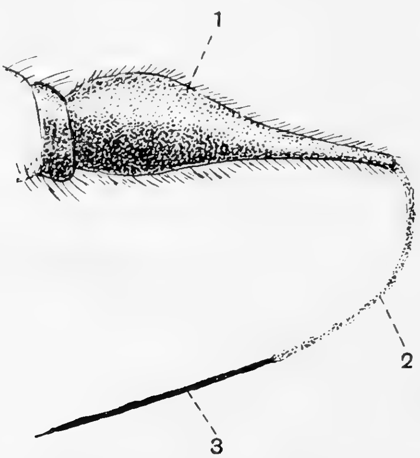

Fig. 1. Extended ovipositor of *U. solstitialis* from left side, × 15. 1, 1st segment of the ovipositor; 2, 2nd, flexible segment; 3, 3rd, piercing segment

The third and last segment is the actual piercing portion of the ovipositor; it is composed of chitin, is about 2·3 mm. long, and except at the extreme narrow tip is about 0·07 mm. in diameter. There are two sharp-cutting blades at the sides of the tip. This segment contains the terminal portion of the oviduct, which opens to the exterior near the tip. During the passage of the ova this segment probably expands slightly.

The ovipositor is extended by pressure, presumably by muscular compression acting on some of the body-fluids. If the swollen portion of the ovipositor is compressed with a pair of forceps, the flexible and piercing segments are readily everted, and they always assume a curved

position which they retain as long as the pressure is applied. The significance of this curvature will be apparent if we consider the structure of the flower-head and the act of oviposition.

As is well known, the young florets of composite flowers are protected by an involucre which is composed of numerous bracts or scales. In the flower-head of *C. nigra* these bracts arise just below the level of the receptacle, and this is the region selected by the fly for the insertion of its ovipositor.

During oviposition the blunt end of the first segment of the ovipositor is placed between the lower scales as described above, and whilst in this position the piercing portion is forced into the tissue of the receptacle. The piercing segment passes downwards and inwards towards the vertical axis of the flower-head, and gradually bends upwards until the tip of the ovipositor finally reaches the space between the tops of the young florets and the overlying bracts. The ova are usually placed in this space; less frequently, however, they are to be found between the young florets. In the latter case the flower-heads are probably older than in the former case, and the florets are longer; consequently the ovipositor is not sufficiently long to reach the space wherein the eggs are usually laid.

Goureau, who correctly described the external appearance and movements of the ovipositor in *U. cuspidata*, believed that the ovipositor was pushed between the florets of open flowers, and that the eggs were then placed on the receptacle of the flower-heads. A similar opinion was also held by Dufour who observed some phases of the life-history of *U. quadrifasciata*. The latter observer, in addition, supposed that the eggs were placed inside the tissue of the receptacle, and further, he believed that the presence of the eggs, and possibly the injection of an irritating fluid at the same time as these were laid, induced "une irritation nutritive du réceptacle transformé alors en placenta"; in other words induced the formation of the gall.

Although the observations of these entomologists refer to species other than the one considered here, yet, as these species are all so closely related to each other, and their larvae also feed in similar flower-heads, it is almost certain that on this point the opinions of these observers were erroneous.

From evidence obtained by opening the flower-heads after oviposition and counting the eggs, and also by counting the number of larval chambers in galled heads, I believe the number of eggs usually laid at one time varies from one to four; where more than four eggs

or larval chambers are present they are probably the result of two or more separate acts of oviposition.

The ovaries of two females were dissected out and the eggs counted in order to determine the number of eggs a female fly is capable of producing. From the ovaries of a female which had laid no eggs, 108 apparently mature ova were obtained, as well as a considerable number of immature ones from the ovarian tubules: the ovaries and oviduct of another female yielded 105 ova; this fly had, however, laid a few eggs. We may safely say that a female of this species is capable of laying at least 100 eggs, and if the immature ova ripen as the season advances, then probably considerably more.

Descriptions of ova, larvae, and pupae.

The ovum of *U. solstitialis* is elongate and usually crescent shaped, with its widest diameter across the centre: the amount of curvature varies, however, examples are met with at times that are almost straight; from the central area the egg tapers towards each end, but more abruptly towards the posterior end which is pointed, than to the anterior or cephalic end which is rounded, and terminated by the prominent micropyle. Bezzi (1913), who discusses the metamorphosis and bionomics of the Trypaneids in general, states that the eggs are "rounded at the two ends"; the egg of this species is therefore exceptional in this respect.

The ova have a glistening white appearance, and when present are readily observed in the flower-heads; the shell or chorion is very thin and quite smooth, and exhibits no sculpturing or pattern on the surface.

In size the ova vary considerably: a number of ova laid by one female varied in size from 0·87 × 0·15 mm. to 1·04 × 0·17 mm.; ova taken from the same fly measured about 0·9 × 0·12 mm. The largest ovum observed measured 1·3 × 0·15 mm.; the average size is about 1–1·02 × 0·15 mm.

Just before deposition the fertilised ovum completely fills the space within the chorion, but shortly after oviposition the embryo commences to diminish in length: in three ova measured one hour after oviposition there was a shrinkage of 0·18 mm., 0·2 mm. and 0·3 mm. respectively, and within twenty-four hours of oviposition the embryo contracts to about two-thirds of its former length. (Fig. 7.) A space thus appears at each end between the embryo and the chorion.

The length of time that elapses between oviposition and hatching, varies somewhat; probably temperature is the controlling factor. In July 1912, larvae were obtained in eight days from the date of oviposition, whilst in June 1913, the shortest time recorded between these two events was eleven days.

The larvae, after hatching, may be found creeping on and between the florets; possibly they feed on these for a short time, but very soon they bore their way through the walls of the corollae and travel down the corolla tubes to the developing ovules. The corollae that contain larvae may be readily distinguished from those that are uninfected. Small circular or elliptical apertures with discoloured margins are visible on florets that contain larvae, and in the majority of cases these apertures are about one-third the length of the floret from the top. Usually each infected floret contains only one larva, but occasionally two larvae may be found, and in one example I found four larvae within a single floret. I have never observed more than a single fully-grown larva in the completed larval chamber; it is therefore probable that where more than one young larva enter a floret all except one eat their way out again and enter other florets. On reaching the base of the corolla tube the young larva bores into the developing ovule and by its activities in this position induces the formation of the gall.

The recently hatched larva measures about $0{\cdot}5 \times 0{\cdot}1$ mm. and has a glistening white appearance; it is cylindrical in shape and slightly thicker at the anterior than at the posterior end. There are two pairs of very small papillae on the anterior segment placed just above the mouth hooks; the lower pair, nearest the mouth, are the sense-organs or palpi, and the upper pair are the antennae (Mik). The pharyngeal skeleton is well developed and very similar in shape to that of the fully grown larva, with the obvious difference that it is very slender and slightly chitinised. At the posterior end of the body the spiracles are visible under a high magnification, as two light-brown spots, and each spiracle possesses three apertures.

The larvae do not grow very rapidly at first; two larvae fourteen days after hatching measured only $0{\cdot}6 \times 0{\cdot}12$ mm., and a larva five weeks old measured $1{\cdot}3 \times 0{\cdot}4$ mm. During the following two or three weeks growth is very rapid; two larvae that were about eight weeks old (Aug. 13th) measured $3{\cdot}5 \times 1{\cdot}5$ mm., and $3 \times 1{\cdot}8$ mm. respectively. The posterior surface of the last segment in both these larvae was becoming dark in colour and strongly chitinised; in larvae preserved early in September these characters are fully developed, and in addition

the area round the mouth is changing to a reddish-brown colour, and undergoing chitinisation. A series of fine grooves which radiate in a backward direction from the mouth are very apparent about this stage. These grooves or striations are present on younger larvae (Aug. 22nd) but in order to see them it is necessary to strip off the cuticle from the anterior part of the body and examine it under the microscope; this area is not chitinised in larvae at this stage; in those larvae, however, where this area has become chitinised the grooves can be much more easily seen. A series of small channels at the sides of the oral lobes in the larva of *Musca domestica* L. is described and figured by Hewitt (1908). The grooves referred to above may correspond to those of the house-fly larva.

The first appearance of the chitinised area round the mouth aperture probably coincides with the nearly completed feeding period. From mid-September to early October the majority of the larvae are fully fed, and they remain head downwards in the larval chambers until pupation commences in the following spring; the larvae reverse their position just before pupation. During the period of feeding, and the growth of the gall, an opening of the larval chamber to the exterior is maintained, and this opening is sufficiently wide to allow the imago to emerge; this opening is situated at the apex of the chamber and is much narrower than the basal part in which the larva hibernates.

The fact that the larva remains head downwards with the strongly chitinised posterior segment uppermost and stretched across the larval chamber where it fits very tightly, suggests the explanation that this is a contrivance for avoiding or preventing the attacks of parasites or other predaceous enemies during the prolonged hibernating period. This suggestion is made by Connold and is, I think, a very probable one. He, however, states that pupation takes place in October. Of course, this may be so in the South of England, although I doubt it.

The larvae of *U. cardui* remain head downwards during the winter (Mik), and Goureau notes that the larvae of *U. cuspidata* also remain in this position until pupation commences. In Dufour's account of the life-history of *U. quadrifasciata* there is no mention of this peculiarity; it may be inferred, however, that the larvae of this species hibernate in a similar manner to those described.

I have never been able to convince myself that frass is present in the larval chambers. In the galls of *Cirsium arvense* caused by larvae of *U. cardui*, Mik found in the upper portions of the larval chambers "Excrementen in der Form von lichtbraunen Krümchen"; possibly

the larvae of *U. solstitialis* derive the greater portion of their food from the sap liberated by rupture of the cells which line the larval chamber. If this assumption is correct, then the absence of frass might be explained, as in this case practically all the food would be absorbed.

The evidence obtained leads to the conclusion that there is only one brood produced each year. Early in September, 1912, I obtained young larvae from flower-heads gathered at Prestatyn and then thought that possibly two broods were produced in one season ; as I have never found pupae or empty puparia during the months of August, September, and October, the conclusion arrived at is that the young larvae obtained in September, were the progeny of late-emerged flies and that there is only one brood produced each year in this part of the country. Goureau states that in France *U. cuspidata* gives rise to two broods in favourable seasons.

The life-history of *Urophora solstitialis* may be briefly summarised as follows :

Egg stage. 8–12 days, from end of June, during July and early August.

Larval stages. Feeding period three months or less ; from early July to early October.

Hibernating stage of larva. About seven to seven and a half months, from early October to mid-May.

Pupal stage. About 4–5 weeks. From mid-May to end of June.

Imago. Length of life uncertain, probably at least a month. (I have kept them alive for three weeks.) They emerge from mid-June to end of July and early August.

There is a certain amount of overlapping in the times given above owing to the extended period of emergence of the imagines.

Description of the mature larva.

There is considerable variation in the size of the fully fed larvae ; thus, three examples taken from one gall in November measured $2{\cdot}8 \times 1{\cdot}5$; $3{\cdot}5 \times 1{\cdot}7$; 4×2 mm. respectively ; the average size of five large larvae was $4{\cdot}4 \times 2$ mm.

Naturally the variation in size is also exhibited by the pupae as will be seen from the measurements of these given further on. A probable explanation of this variation is that the smaller individuals develop from eggs laid by late-emerged flies and consequently the feeding period is much shorter than in the case of those which develop from eggs laid

earlier in the season ; it is also possible that where several larvae, say eight to ten are feeding together in one flower-head, there is not sufficient nourishment to enable them all to reach a large size.

The larvae are ellipsoidal in shape ; the anterior end is bluntly pointed and the posterior end sharply truncate, and the greatest width is across the anterior third of the body (Fig. 9). With the exception of a very few extremely small hairs on the posterior surface of the last segment, the body of the larva is completely smooth and free from bristles or spines ; Bezzi (1913) in his very useful account of the Trypaneidae states that " the under surface [of Trypaneid larvae] bears transverse rows of small black spines directed backwards," and further, that " the anal end is somewhat impressed, contoured by a variable number of fleshy points or tubercles, some of which bear also chitinous spines." Neither of these characters is present in the fully grown larvae of this species, nor according to Mik in those of *U. cardui* ; in his description of the larvae of this species he says they showed " keine Spur von Dornchen " and " die Larve ist also völlig kahl, glatt " ; as far as can be judged from the descriptions of the larvae of *U. cuspidata* and *U. quadrifasciata* given by Goureau and Dufour, the larvae of these species possess neither spines nor anal tubercles. The larvae of these four species differ therefore from the majority of Trypaneid larvae in these two features, which, according to Bezzi, are possessed by Trypaneid larvae in general.

In colour the fully grown larva is pale creamy white, except at the ends ; the two anterior segments are reddish brown, and the posterior segment is pale yellow round its anterior border, merging into a very dark chestnut-brown, almost black, colour on its posterior surface ; the two areas surrounding the spiracles are lighter in colour.

The segmentation of the larva is well defined except at the anterior end ; Bezzi states that the number of segments in Trypaneid larvae generally is usually fourteen. I have been able to distinguish only thirteen segments in these larvae, and Goureau regarded the larvae of *U. cuspidata* as probably possessing twelve segments, excluding the head ; there may be a fusion of two segments in the cephalic region of these *Urophora* larvae. On the ventral surface of the middle segments there are indications of creeping-pads (Kriechschwielen).

The mouth appears as a slit whose long axis is dorso-ventral ; the antennae and sense-organs are difficult to make out on fully grown larvae, in fact I have never been able to make them out satisfactorily ; probably they are retracted into the body together with the cephalo-

pharyngeal apparatus when chitinisation of the oral segment takes place. They can be observed on larvae about 7–8 weeks old, but they are very minute, measuring about 12μ in length and 8μ in diameter; in larvae of this age there can be seen in addition, a number of small papillae bordering the dorsal and dorso-lateral lobes of the mouth. The fine radiating grooves which surround the mouth have already been referred to.

The complete cephalo-pharyngeal skeleton consists of three pairs of sclerites and an unpaired V-shaped sclerite. The mandibular sclerites or "great hooks" each possess a prominent anterior tooth, a smaller median tooth, and a basal tooth or spur, and each sclerite is perforated near the base by a small aperture; Hewitt (1907) described a similar perforation in the corresponding sclerites of the larva of *Anthomyia radicum* L. The mandibular sclerite articulates with the intermediate or hypostomal sclerite, which in *U. solstitialis* appears to be fused with the posterior or cephalo-pharyngeal sclerite; in this latter sclerite there is a deep indentation posteriorly between its dorsal and ventral prolongations, and these again are frequently bifurcated. With careful observation a membrane can be observed surrounding each prolongation extending some distance behind them; a corresponding membrane is figured by Mik in *U. cardui.*

A V-shaped sclerite is situated beneath the hypostomal sclerites; each free end of the V articulates with a ventral projection of the hypostomal sclerite on each side, and the apex of the V is placed near the bases of the two mandibular sclerites (Fig. 8). It may be called the sub-hypostomal sclerite. The examination of a number of preparations of the cephalo-pharyngeal apparatus reveals numerous slight variations in size, shape, and amount of chitinisation of these structures; these variations are more especially noticeable in the posterior sclerite. Interposed between the mouth and the mandibular sclerites there is found another strongly chitinised body; this only becomes apparent towards the close of the feeding period, and probably consists of the closely apposed and chitinised sides of the oral lobes.

In appearance and structure, the anterior and posterior spiracles are very similar to those of *U. cardui* figured and described by Mik; he described the anterior pair as being situated on the second segment (of the pupa). In *U. solstitialis* the anterior pair are placed dorso-laterally on the third apparent segment, and near its posterior border, about 0·3 mm. apart (Fig. 11). They are yellowish-brown in colour and do not project above the surface of the body; each spiracle consists

of three short papillae joined together at the base; a slightly elliptical aperture is situated at the apex of each papilla, and these lead into the spongy felted-chamber (Filzkammer) which is in communication with the longitudinal canal. In some preparations I have been able to distinguish a membrane between the inner boundary of the felted-chamber and the longitudinal tracheal canal, and this is perforated by a small aperture 4μ in diameter (Fig. 15).

The posterior segment bears the anus and the posterior spiracles; it is wider on the ventral aspect, where the anus is situated in the mid-ventral line, than on the dorsal and lateral aspects. A shallow horse-shoe shaped depression is present on the posterior surface of this segment at a short distance from its dorsal and lateral borders, and a slight depression, situated just dorso-median to the posterior spiracles, is also apparent. The surface is marked with a number of very fine grooves or lines which run in various directions; round the spiracles they are arranged concentrically. A number of small darker-coloured areas may be observed on various parts of this surface, particularly on the ventral portion; they indicate the points of attachment of muscles (Fig. 12).

The posterior spiracles are situated slightly nearer the dorsal than the ventral aspect, as in the larva of *U. cardui*, and they are about 0·7 mm. apart. They are larger than the anterior spiracles and darker in colour; anatomically they are very similar to these but the apertures are more definitely elliptical in shape and are arranged in a radiate manner. They project very slightly from the body surface (Fig. 14). In one instance a variation in the number of apertures in the left posterior spiracle of a larva was noticed; this spiracle possessed four apertures instead of the usual number three.

In concluding this description of the larva, the small number of lobes or papillae of the anterior spiracles as compared with the number on the anterior spiracles of many other Trypaneid larvae may be noted; Banks (1912) describes nine Trypetid (Trypaneid) larvae whose anterior spiracles each bear a large number of lobes varying from about fifteen in *Ceratitis capitata* Wied. and *Rhagoletis pomonella* Walsh, to thirty-eight lobes in *Dacus ferrugineus* Fab.; whereas in the larva of *U. solstitialis* and *U. cardui* (Mik) three lobes only are borne on each anterior spiracle.

Description of the pupa.

The pupae vary considerably in size as may be expected from the great variation in size exhibited by the larvae ; among ten selected for measurement the largest measured 4·3 × 2 mm. and the smallest 2·8 × 1·4 mm., the average size of the ten pupae was 3·6 × 1·7 mm. In shape they are cylindrical, obtuse or bluntly pointed at the anterior end, and obliquely truncate dorso-ventrally at the posterior end ; during pupation there is little or no alteration in length but the pupa is more parallel-sided than the larva (Fig. 10).

The colour varies from light yellow to dark reddish-brown ; the majority, however, are of the lighter colour, and in all specimens the first three or four segments and the last one are much darker in colour than the intermediate ones. These anterior and posterior segments vary in colour from reddish-brown to dark chestnut-brown or black. On the surface of the puparium a number of anastomosing wrinkles are seen which vary in direction in different parts of the same ; they are more or less parallel to the segmental grooves on the dorsal and ventral aspects of the middle-segments, but at the sides they run obliquely. These wrinkles are darker in colour than the smooth portions of the puparium, and represent wrinkles of the larval skin which become more apparent through shrinkage undergone during pupation.

At the anterior end the radiating grooves which run in a backward direction from the mouth are very noticeable, and the anterior spiracles are visible under a good lens as two brown spots in the position described in the larva.

The posterior aspect exhibits the same features as in the larva and requires no further description ; there is a variable amount of wrinkling around the margin of the last segment, but well-marked ridges similar to those figured by Mik on the posterior surface of the pupa of *U. cardui* are not apparent. The pupae have a dull glistening appearance ; Mik described the appearance of the pupa of *U. cardui* as " etwas seidenglänzend."

Connold's figure of the pupa of *U. solstitialis* is incorrect ; the object figured resembles a syrphid larva.

Effects of larvae on production of seeds in galled flower-heads of Centaurea nigra *L.*

In order to obtain some definite information concerning the effects of the *Urophora* larvae on the production of seeds, a number of plants were collected and a series of counts made. Perfect accuracy is not claimed for the results obtained, as, owing to various circumstances, the conditions were such that a high degree of accuracy could not be expected. The plants were collected on Oct. 1st, 1913, that is to say, late in the season, when many of the seeds had certainly escaped, in addition to those probably taken by seed-eating birds. As the plants, however, were collected within a space of about twenty square yards, it may be assumed that these factors affected all the plants in this area in a more or less similar manner. Fifty plants, single shoots cut off at the ground-level, were selected, and these bore 147 flower-heads; twenty-four of these, however, were immature and therefore disregarded. Of the remaining 123 heads, seventy-four or 60·1 per cent. contained galls, whilst forty-nine or 39·8 per cent. were ungalled. Nine of the galled heads contained no seeds, and these for the purpose of calculation were neglected; from the remaining sixty-five galled heads 1077 seeds were obtained, averaging 16·5 seeds per head.

Twenty-five of the forty-nine ungalled heads were rejected for various reasons; ten contained no seeds whatever, whilst the seeds in the remaining fifteen were more or less eaten by seed-eating lepidopterous and free living dipterous larvae.

From the twenty-four ungalled heads that were considered countable, 755 seeds were obtained, averaging 31·4 seeds per head. Thus showing a reduction of nearly 50 per cent. (31·4 – 16·5) in the number of seeds produced in the galled heads, compared with the number produced in ungalled heads. The number of seeds (31·4) per head obtained from these particular heads is very low, and would be misleading if one were to assume that this was the average number obtainable from normal well-grown flower-heads of *Centaurea nigra*.

It may be explained that the soil on which the above plants were grown was very poor and stony, and the specimens were gathered late in the season when some of the seeds had escaped, as stated above; these considerations may help to explain the small average number of seeds per head.

By way of contrast may be quoted the number of seeds obtained from some flower-heads of the knapweed gathered by Prof. Hickson,

near St Bees, Cumberland, early in September of the same year. These results give a more accurate idea of the number of seeds present in well-developed flower-heads of this weed.

From twenty-seven flower-heads 2045 seeds were obtained; averaging 75·7 seeds per head; one flower-head contained 103 seeds, whilst the smallest number found in one head was sixty-two. A collection of flower-heads was also made at Port Erin, Isle of Man, early in September, and one head yielded the very high number of 109 seeds.

These figures indicate the large number of seeds that may be ripened in a fully-developed flower-head of this plant, and it may be of some interest to make an estimate of the number of seeds that a single plant of this species is capable of producing.

Several plants of the knapweed were grown for experimental purposes last summer, in my garden at Northenden, in Cheshire, and one of them gave rise to several particularly lusty shoots; one of these bore fifty-one flower-heads, and if it is assumed that each head ripened only thirty-one seeds (the average number obtained from heads gathered at Prestatyn) we obtain the number 1581 seeds producible on one single shoot. A vigorous plant growing in good soil would give rise to at least three or four shoots, so that several thousands of seeds may be produced on one plant. Long (1910, p. 175) remarks that "knapweed (*Centaurea nigra* L.) known under a variety of names as Hardheads, Hardhack, Blackhead, is a too common weed of pastures and meadows," and in view of the above estimate of its seed productivity, this is not surprising. Were it not for the fact that several insect larvae and birds feed on its seeds it would be even still more abundant.

A germination experiment was also made to test the difference, if any, between the seeds ripened in galled heads and those in ungalled heads, with regard to their vitality or germinative power.

A large number of seeds from the ungalled flower-heads collected in October were taken and mixed together; after rejecting all seeds that showed evidence of injury, *i.e.* indications of having been partially eaten by other insect larvae, 100 seeds were separated without exercising any selection. These were placed on moist blotting paper in a seed-germinating apparatus, and kept at a temperature of 26° C. From these seeds eighty-nine seedlings were obtained, equivalent to 89 per cent.

In a similar manner 200 seeds were selected from the galled flower-heads that were collected on the same date and these were placed in the germinating apparatus at the same time. That is to say, both lots of seed were collected at the same time and place, and germinated under

similar conditions. Of these seeds only fifty-seven germinated, equivalent to 28·5 per cent.

The percentage of germination in the seeds tested from galled flower-heads was thus reduced 60·5 per cent. owing to the presence of *Urophora* larvae in the receptacles of the flower-heads; probably the nourishment that normally goes to the developing seeds, becomes diverted to the growing larvae and also to the formation of the thick-walled woody gall.

This experimental result coincides with the indications given by the appearance of the seeds usually obtained from galled flower-heads; many of these seeds are shrivelled, and smaller than the majority of those collected from ungalled heads.

Thus in addition to a reduction in the number of seeds produced in the galled flower-heads, the number of seeds capable of germination is also reduced. Taking into consideration the smaller number of seeds obtained from infected flower-heads, and also the reduced vitality of those actually ripened, as indicated by the above experiments, it may be stated that the presence of the larvae of *Urophora solstitialis* in the flower-heads of *Centaurea nigra* reduces the number of effective seeds in these infected heads at least fifty per cent.

Although the Trypaneidae or fruit-flies are justly regarded as injurious from the economic standpoint because many of them are very destructive to various cultivated fruits and to vegetable life in general, yet those species whose larvae feed on, or in, the stems, leaves, flower-heads and seeds of the weeds of cultivated land, may be regarded, from the agricultural point of view, as beneficial. The result of the activities of their larvae is that the plants fed upon are affected adversely, and in many cases, as in the case of the species considered in this paper, the production of seeds is directly checked; the distribution of the weeds attacked is therefore restricted, even if only to a moderate extent.

The question occurs as to whether destructive weeds could be appreciably reduced by encouraging certain species of insects which attack the seeds thereof. It is hoped that the present paper will suggest to others the possibilities for further research and experiment in this field of enquiry, which is fully worthy of attention from the economic entomologist.

Parasites.

Three species of Chalcids and one Braconid emerged from the flower-heads in May 1912 and 1913, but in very small numbers; presumably some of these were parasitic in the *Urophora* larvae. The Chalcids have not as yet been identified; Mr Claude Morley, however, has kindly named the Braconid, it is *Bracon minutator* Fab., and probably parasitic on the lepidopteron *Parasia metzneriella* Stt. Brischke (1882) records this parasite from the larvae of *Sesia* (*Bembecia*) *hylaeiformis* Lasp. (not a British species); Marshall (1885) states that Elisha bred two females of this Braconid from the lepidopteron *Argyrolepia zephyrana* Tr. It therefore appears probable that *Bracon minutator* is parasitic on lepidopterous hosts. Under the description of *Bracon variator* Nels., Marshall says "It is doubtful whether this *Bracon* is a parasite of certain small curculios (*Cionidae*) or of flies of the genus *Trypeta*" and further on he states that "Giraud records *B. nigripedator* Nees, from *Urophora solstitialis* L.; and Fitch once obtained a Bracon, now lost, from galls of *Centaurea* inhabited by the same fly."

With regard to these records of parasitic hymenoptera obtained from flower-heads of *C. nigra* and other composite plants, I would remark that unless it is proved that dipterous larvae and pupae alone are present therein, it is incorrect to state definitely that they are the hosts of the parasites obtained, inasmuch as a single flower-head may contain the larva or pupa of a lepidopteron in addition to those of diptera.

Kaltenbach states that *Eurytoma aterrima* Schr. (*verticillata*) is parasitic on *U. solstitialis*, and probably also *Trigonoderus amabilis* Walk. and *Semiotellus* (*Semiotus*) *diversus* Walk. Walker (1833–37) records these three Chalcids from near London but does not give their hosts.

Mr C. Morley (1908), from a quantity of dried heads of *Centaurea nigra* gathered in March, 1907, beneath fir-trees, obtained both sexes of a *Pteromalus* in May, and numerous *Bracon minutator* ♂ in April; he also obtained one specimen of *Pimpla sagax* Htg. on April 26th, and of this specimen he says (p. 81) "Its host was undoubtedly *Urophora solstitialis*, many of which emerged during the following June; unless, of course, its presence there were purely accidental and its true association were with the overhanging conifers, in which case it would surely have shown itself in the jar in the course of the preceding month." In view of the fact that with one exception, viz. *Anthonomus pomorum* L. all the recorded hosts of this ichneumon are lepidopterous, and as the

larvae of at least three species of lepidoptera have been recorded from *Centaurea nigra*, the evidence adduced by Mr Morley that *U. solstitialis* is a host of *Pimpla sagax* is hardly conclusive. It seems more probable that the single specimen obtained by him either emerged from a lepidopterous host, or that its presence in the flower-heads was accidental, as he indeed suggests.

Five hymenopterous larvae, probably of a Chalcid, were obtained from 259 larval chambers examined in October, 1913, equivalent to two per cent. Each of these larvae occupied a chamber that had previously contained a *Urophora* larva. In one case there was direct evidence that the hymenopteron had fed on the dipterous larva, as the parasitic larva was inside a portion of the cuticle of the *Urophora* larva and had evidently been feeding on the latter. From material in hand I hope to be able to breed out a further supply of these Chalcids, to get them identified, and to obtain the percentages.

Remarks on Gall-formation and on other inhabitants of the flower-heads of Centaurea nigra.

The process of gall-formation in the flower-head of the host plant exhibits some very interesting features. To determine whether the formation of this gall is induced mechanically by the feeding habits of the larva, or whether the latter secretes an irritant fluid which causes the abnormal growth, would require further observations. The tissues of the receptacle near the ovule attacked commence to swell up shortly after the larva begins to feed, and in a comparatively short time the size and shape of the future hibernating chamber of the larva are marked out in the gall, although the larva is far from its full size. In a longitudinal section of a gall that contained a larva about four weeks old and 1·3 mm. in length, the outline of the future hard-walled chamber could be clearly distinguished. A thin layer of woody tissue is developed within the hypertrophied tissue that the larva is feeding on, and a thick layer of soft nutritive tissues is left within this woody layer and the space occupied by the larva (Fig. 5); this nutritive layer is connected at the base of the chamber with the vascular system of the plant.

During the period that elapses between this stage and the attainment of the fully fed one, the larva gradually eats away this layer of soft tissue, until finally when the growth of the larva is complete the layer of soft tissue has been absorbed and the hard wall of the chamber reached (Fig. 6); meanwhile the wall becomes more lignified and

harder, and the tissue between adjacent chambers that have fused together also becomes drier and harder, and in this manner the hard plurilocular gall is produced (Figs. 3 *a* and 4).

The interesting fact revealed during this process is that the stimulus produced by the presence of the larva in the embryonic tissue of the developing ovule, and in the hypertrophied receptacle, induces a reaction of the plant to form a structure that is possibly protective to the plant itself, but which is also at the same time exactly suited to the requirements of the fully-grown larva, forming as it does a very efficient means of protection to the larva during the prolonged period of hibernation.

Several larvae, pupae, and imagines of *Parasia metzneriella* Stt. were obtained from the flower-heads during this investigation ; 30 % of the heads examined were found to contain these lepidopterous larvae. By far the greater number of larvae were found in chambers that had originally been made by *Urophora* larvae, and it is a subject for further investigation to find out what becomes of the original occupants of these chambers.

Eleven larvae of an unidentified dipteron were found feeding on the ripening seeds ; they were found in 9 per cent. of the heads examined. Small orange-coloured larvae of a Cecidomyid were very abundant, almost every flower-head examined contained several specimens.

A lepidopterous larva which differed from that of *P. metzneriella* was found feeding on the seeds in 25 per cent. of the flower-heads collected by Prof. Hickson at St Bees ; as the moth has not yet emerged, I have not been able to identify the species to which it belongs.

The larvae of two species of *Coleophora*, *C. alcyonipennella* Koll. and *C. conspicuella* Z. are recorded from *Centaurea nigra*. The larvae found at St Bees may belong to one of these two species.

Summary.

1. A description of *Urophora solstitialis* L. and an account of its systematic position and geographical distribution are given, together with an abstract of the work of previous observers on this species.

2. A list of its British and continental food-plants is given ; the records of the latter show that on the continent the larvae feed on various species of thistles, and on three species of *Centaurea*, but not on *Centaurea nigra*, whereas with the exception of one record of their occurrence on *Serratula tinctoria*, the larvae in this country are recorded as feeding exclusively on *Centaurea nigra*.

3. The life-history, ovipositor, and method of oviposition are described, and descriptions and figures of the ova, larvae, and pupae are given. The life-history is summarised on p. 148.

4. It is shown that owing to the formation of galls induced by larvae of *U. solstitialis* in the flower-heads of this weed a reduction in the number of seeds is effected amounting to about 50 per cent. in the heads examined. The germinative capacity of the seeds produced in these galled heads was also adversely affected. In the germination experiment described 60·5 per cent. fewer seeds germinated from galled flower-heads of *C. nigra* than from ungalled ones. At a moderate estimate the number of seeds rendered non-effective in galled flower-heads of *C. nigra* is placed at 50 per cent. It is pointed out that Trypaneids, whose larvae adversely affect the weeds of cultivated land, may be regarded as beneficial.

5. A short account and discussion of the recorded parasites of *U. solstitialis* is given.

6. Some interesting features observed in the process of gall-formation are referred to, and a few notes are added on some other insect inhabitants of the flower-heads of *C. nigra*.

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Summary of results obtained from the examination of 50 *shoots of* Centaurea nigra *gathered Oct.* 1*st*, 1913, *at Prestatyn, North Wales.*

45 of the 50 shoots carried galled flower-heads, *i.e.* 90 % were infected.	No. of heads obtained from 50 shoots, 147; average, 3 per shoot. 24 were immature; of the remaining 123, 74 (60·1 %) contained galls and 49 (39·8 %) were ungalled.	No. of heads	No. of larval chambers per head	Total No. of larval chambers, 259; average, 3·5 per head	No. of seeds obtained from 65 galled heads, 1077; average 16·5 seeds per head.
		1	11		
		1	10		
		1	9		
		2	8	Total No. of larvae obtained, 170	No. of seeds obtained from 24 ungalled heads, 755; average, 31·4 seeds per head.
		3	7		
		5	6		
		6	5		
		13	4	No. of chambers found either empty or containing hymenopterous or lepidopterous larvae, 89.	200 seeds from galled heads on germination yielded 57 seedlings (28·5 %).
		14	3		
		10	2		
		18	1		
		74	Total 66		100 seeds from ungalled heads yielded 89 seedlings (89 %).

Remarks. The greatest number of larval chambers found in a single flower-head of the above fifty examined was eleven, and this number occurred only once; eighteen heads contained only one larval chamber each. The greatest number of chambers found in one head during the investigation was thirteen.

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EXPLANATION OF PLATES.

PLATE XI.

Fig. 1. *Urophora solstitialis.* Female, ×5; ovipositor partially extended.

Fig. 2. Vertical section through young flower bud of *Centaurea nigra*, showing eggs *Ov.* of *U. solstitialis in situ.* 24 hours after oviposition. ×9.

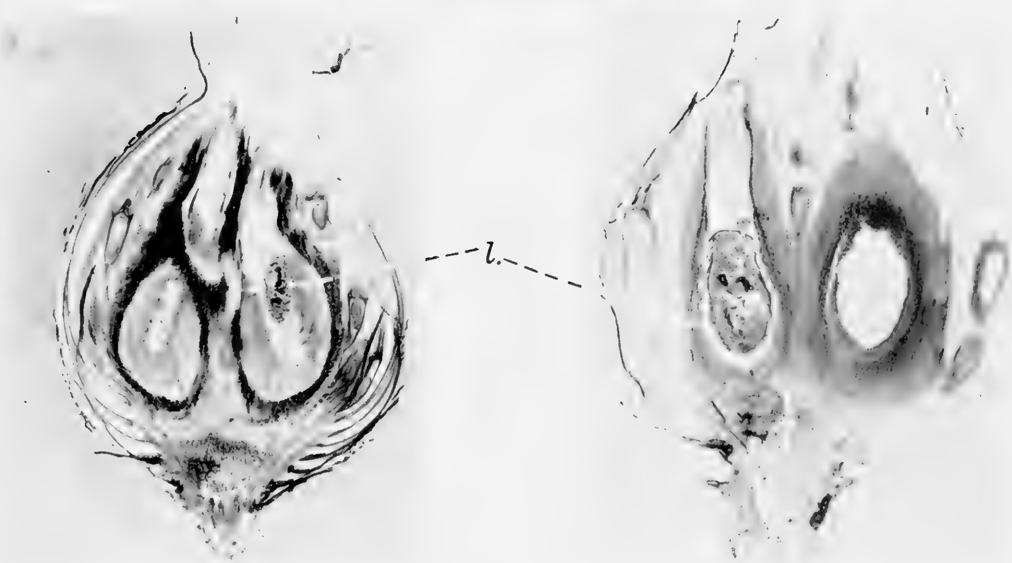
Fig. 3. A. Ungalled receptacle of *C. nigra.* × 2.
B. Galled ,, ,, ,, ,,

1

A 3 B

2

4



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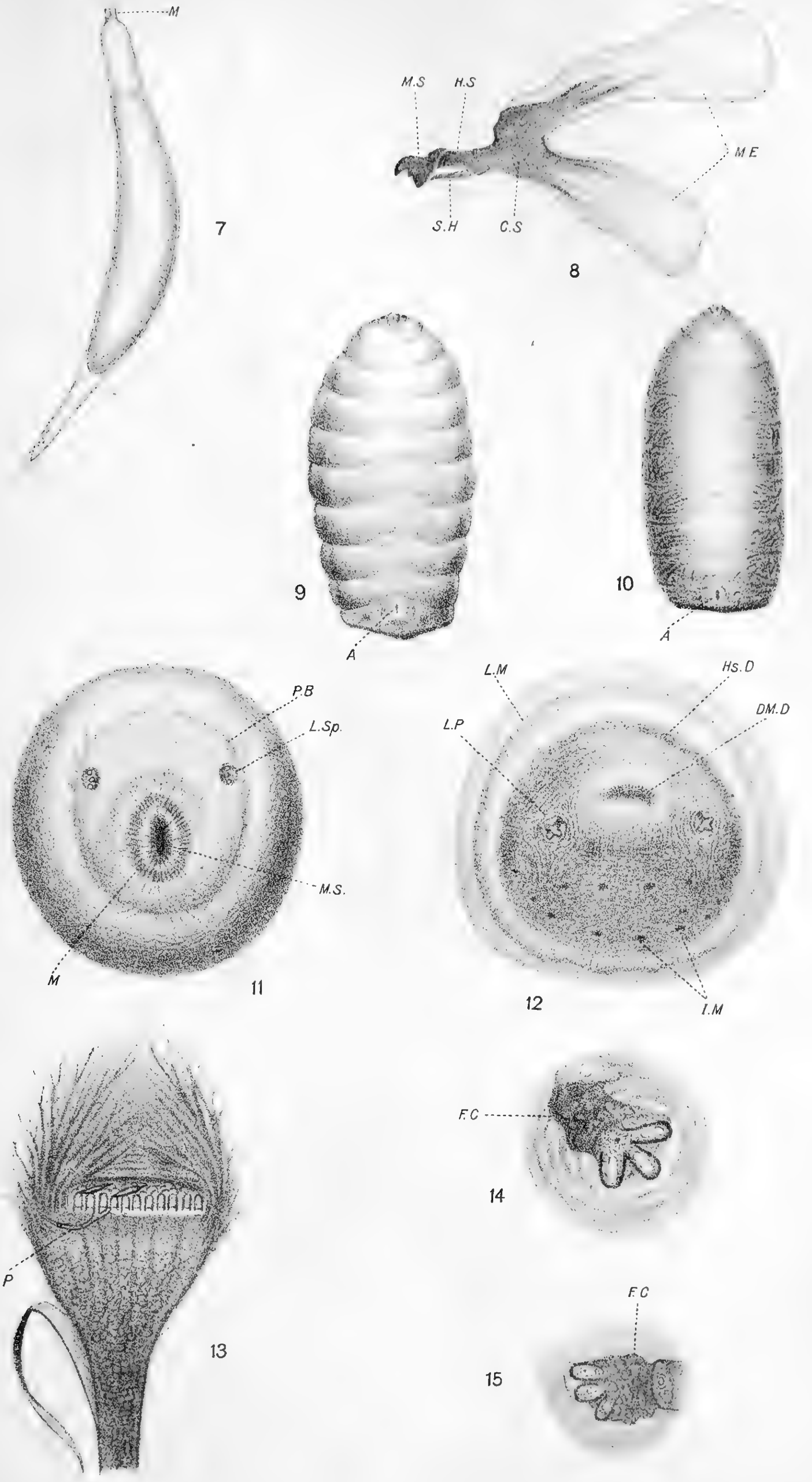
Urophora solstitialis.



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Cambridge University Press.

UROPHORA SOLSTITIALIS.

Fig. 4. Vertical section through three galled flower-heads of *C. nigra* showing the chambers in which the larvae hibernate during winter, and where pupation takes place. The left hand one contains a pupa. ×2.

Fig. 5. Vertical section through a galled flower-head of *C. nigra*; the section shows the hard woody walls of two chambers; the right chamber contains a section of a larva and shows the thick layer of nutritive tissue that is separated from the remainder of the receptacle when the woody layer is developed. The section is slightly tangential, and the larva is younger than the one in Fig 6. ×5. *l.* section of larva.

Fig. 6. Section similar to Fig. 5 containing an older larva in the left chamber, the nutritive layer has been almost eaten away by the larva, and the woody wall reached. ×5. *l.* section of larva.

PLATE XII.

Fig. 7. Egg of *U. solstitialis.* 24 hours after oviposition. ×50; *m.* micropyle.

Fig. 8. Cephalo-pharyngeal skeleton of mature larva from the left side. ×120. *m.s.* mandibular sclerite; *h.s.* hypostomal sclerite; *c.s.* cephalo-pharyngeal sclerite with deep indentation between dorsal and ventral processes which exhibit further bifurcations; *s.h.* sub-hypostomal sclerite; *m.c.* membrane surrounding each process of the cephalo-pharyngeal sclerite.

Fig. 9. Mature larva, ventral aspect. ×10. The larva was slightly lifted upwards anteriorly bringing into view the mouth-slit and the anterior spiracles. *a.* anus.

Fig. 10. Puparium, ventral aspect. ×10. *a.* anal scar.

Fig. 11. Anterior view of mature larva. ×45. *p.b.* posterior border of third segment. *l.sp.* left anterior spiracle. *m.s.* mouth-slit with the dark chitinised sides of the oral-lobes. *m.* posterior margin of the chitinised area surrounding the mouth.

Fig. 12. Posterior view of last segment of mature larva. ×50. *l.m.* lateral margin of last segment *hs.d.* horse-shoe shaped depression. *dm.d.* dorso-median depression. *l.p.* left posterior spiracle. *i.m.* indications of muscle-attachments which appear as dark areas on the surface.

Fig. 13. Vertical section of flower-bud of *C. nigra* showing the passage *p.* made by ovipositor during the process of oviposition. ×5. The ovipositor had passed on both sides of the third floret from the left-hand side, as indicated in the drawing.

Fig. 14. Right posterior spiracle of mature larva viewed from above. ×200. *f.c.* felted-chamber (Filzkammer).

Fig. 15. Left anterior spiracle of nearly mature larva viewed from above. ×200. *f.c.* as Fig. 14.

Note. In figs. 14 and 15 the felted-chamber (*f.c.*) is displaced laterally. In the larva the chamber is directly beneath the spiracular openings.

Figs. 7, 8, 11, 12, 14, and 15 were drawn by the aid of the Zeiss-Greil drawing apparatus.

A BRACONID PARASITE ON THE PINE WEEVIL, *HYLOBIUS ABIETIS.*

By J. W. MUNRO, B.Sc. (Agr.), B.Sc. (Arb.), Edin.

The following notes are the result of observations made on pine weevils and parasites collected in a plantation on the estate of Banchory Devenick near Aberdeen. The plantation in question was formed in the spring of 1911, a year after the removal of the old crop which was a pure wood of Scots pine. The stumps and roots of this old wood afford ideal breeding places for the pine beetle (*H. piniperda*) and the pine weevil (*Hylobius abietis*), and they are to be found in considerable numbers.

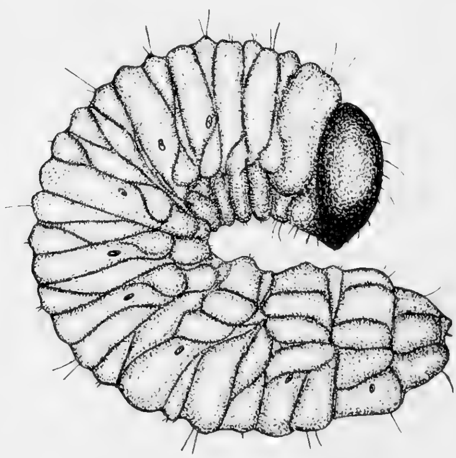

Fig. 1. Larvae of *H. abietis*. ×6.

The work of the pine weevil is familiar to all interested in forestry. It is harmful only in the adult state and does considerable damage by gnawing the tender bark of young conifers causing them to wilt and die. Where conifers are not to be got it will readily attack birch, mountain ash, and oak.

In the larval stage *Hylobius* is harmless. The adult deposits her eggs in or under the bark of the stumps of various conifers but prefers Scots pine. The larva on hatching out, commences to tunnel between the bark and the sapwood, and when full grown pupates at the end of this tunnel, either in a cavity or hook gallery in the sapwood, or in a cavity in the bark. The tunnels are filled with frass, consisting of tiny chips of wood bitten out by the larva and passed through its body.

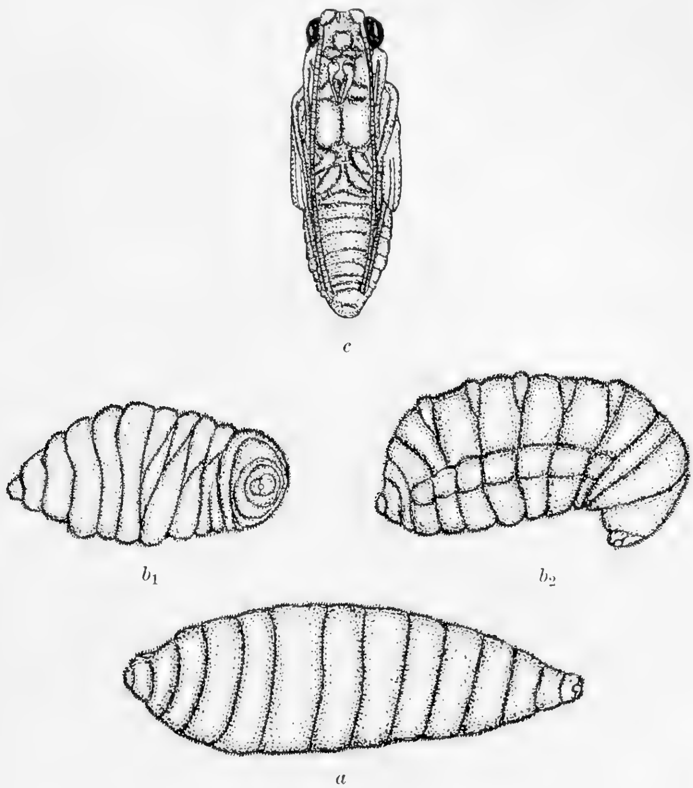

Fig. 2.

a, b. Larvae of *B. hylobii.* × 12. (*a* after first moult. *b* after second moult.)
c. Pupa of *B. hylobii.* × 12.

The whole of the larval life is passed in such a tunnel. In the spring of 1912 I noticed a few tiny cocoons lying in one of these tunnels but I attached no importance to them at the time. In July of last year, however, I found several weevil larvae apparently in the resting stage, which were attached by a small legless maggot feeding externally on

them. I collected a number of weevil larvae both attacked and immune, and also a number of the attacking maggot. In some cases the weevil larvae were sucked quite flat and in a few days all those which had been attacked were in this condition. Accordingly I supplied the parasitic larva with more grubs and found that they readily fed on them, crawling two or three inches to reach their new prey.

These parasitic larvae measured somewhat over $\frac{1}{4}$ inch in length, and were covered with very short reddish brown hairs. Unfortunately I was unable through lack of proper instruments to make a close examination of them and I could not make out the mouth parts. Observation showed, however, that they fed through the skin of their host and were purely external parasites. In September the parasites ceased feeding, and a few days after they moulted and became more definite in shape, and I assumed then that they were Hymenopterous. A fortnight later, on September 25th, they commenced spinning silky cocoons and in a few hours they were completely hidden. All through the winter I examined a few of these cocoons every week, but no alteration in the external appearance of the enclosed larvae was visible until February 20th, when in two out of five cocoons I found pupae. Nine days later the first imago emerged which I recognised as a Braconid of some sort. At the date of writing, April 14th, flies are still emerging from the later gathered cocoons.

Dr MacDougall informs me that three years ago he obtained a Braconid parasite on *Hylobius*, but in such a battered condition as to be unrecognizable. So far as I have been able to ascertain I know of no other British record of a Braconid on *Hylobius*. In Ratzeburg's *Ichneumon der Forstinsekten*, however, there is a short account of the rearing by Nordlinger of 40 ♀♀ and 4 ♂♂ from the larvae of *H. abietis*. I may be permitted to quote Ratzeburg's account. "Nordlinger bred 40 ♀♀ and 4 ♂♂ from this species (*Hylobius abietis*) each of whose larvae supports about ten parasites. The cocoons of the latter are firm, oat-shaped and papyraceous, woven among their hosts frass and dead bodies, and often constructed at the end of the beetles' tunnels beneath fir bark." This description agrees in every respect with my own observations and accordingly I looked up Ratzeburg's description of the species which he calls *Bracon hylobii*. It again agrees with the insects I have bred out, and as I have been unable to identify my specimens with any of the Bracons in the South Kensington collection, or with those described by Marshall, I think it highly probable that the species I have reared are

B. hylobii. If so they are a species new to Britain, and in order to be sure of this I have sent specimens for identification to Dr Szepligeti in Budapest.

Ratzeburg's description of the species is as follows: "B. hylobii. $1\frac{1}{2}$–$2\frac{1}{2}$ mm. Outer and inner discoidal cells equally long. Second cubital cell a little larger than the first. Antennae of ♀ 31 jointed. The ovipositor as long as the abdomen and tending to curve upwards. Head approximately as broad as the thorax. All the legs and the greater part of the first half of the abdomen reddish brown. In the ♀ only the middle of the first segment is black. In the male the first

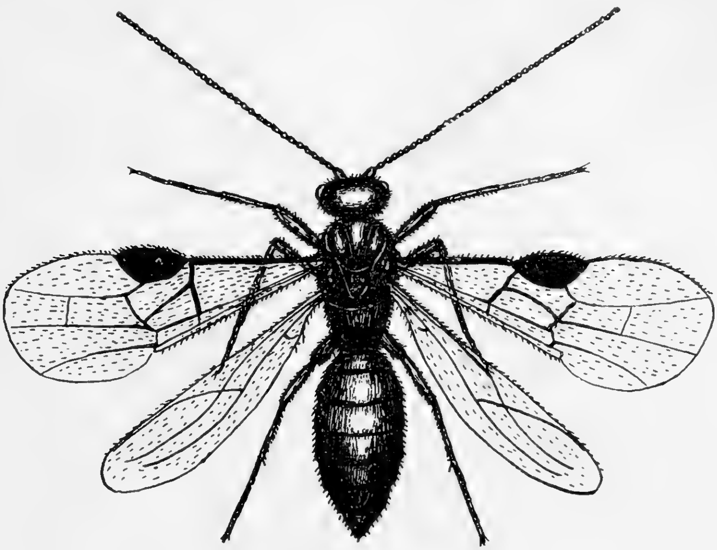

Fig. 3. *B. hylobii* ♂. × 15.

ring may be almost quite black and the last or posterior half of the abdomen in both sexes is quite black. The thorax and head black except in certain females when part of it is brownish."

Ratzeburg expresses doubt as to making it a species, but he considers that the shape and size of the discoidal cells entitle it to that distinction from its near neighbours *B. immutator* and *B. spathiformis.*

Messrs Elliott and Morley in their Hymenopterous parasites of the Colioptera refer to Ratzeburg's species but do not quote his description. These references are the only two I have been able to obtain on the subject[1].

[1] Brischke, C. G. A. Die Ichneumoniden der Provinzen West- und Ostpreussen. *Schrift. Naturfors. Gesell* Danzig Neue Folge, v, 1882, p. 135 (records the ♀ of *Bracon hylobii* but makes no comments thereon).

The degree of parasitism by *B. hylobii* on the pine weevil may be of interest. In winter 1911 I observed no cocoons. In the spring of 1912, two years after the old crop was removed and presumably in the second year of the beetles' occurrence there, I observed a few cocoons, while in 1913 and 1914 every third pupating chamber was occupied by them. This represents parasitism in the third and fourth years of the pest of over 30 per cent.

I think I do not exaggerate when I suggest that *Bracon hylobii* Ratz. may prove of considerable value in combating the pine weevil, which is every year becoming more and more common in newly formed

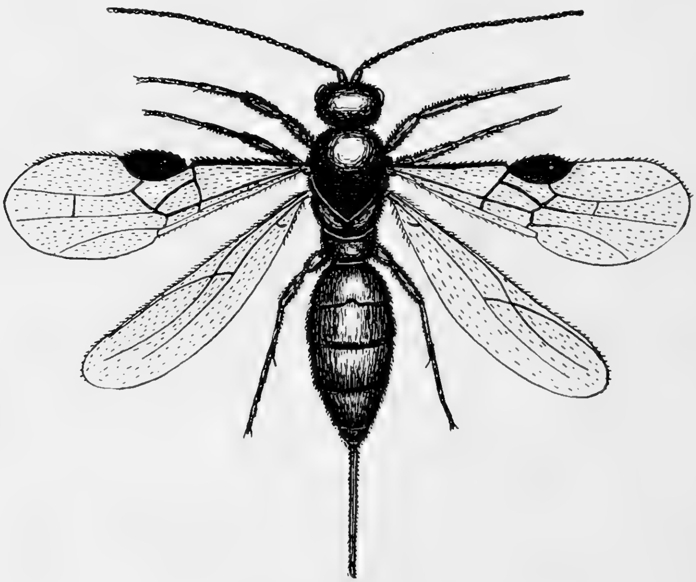

Fig. 4. *B. hylobii* ♀. × 15.

plantations, especially in Scotland. The parasite is, in all probability, fairly common where *Hylobius* is found. The fact that it has hitherto apparently been unrecorded does not imply that it is scarce. The persons most interested in *Hylobius*, the forester and the factor, are interested only in the adult beetle when it begins its attacks on their plantations, and any measures they may take against it are as a rule confined to the trapping and collecting of the adult. The larvae are rarely considered, and though they were disturbed and examined, the forester is neither sufficiently interested nor sufficiently educated to pay any attention to the cocoons, or larvae of a parasite, though he found them.

Parasites have already been used with success in combating other destructive insects ; notably Professor Lefroy's introduction of *Rhogas Lefroyi* into the Punjaub, to combat the boll worm, and more recently Pierce and Townsend have shown that Hymenopterous parasites play a very important part in controlling the cottonboll weevil in the States. Pierce found that of 2800 weevils, 591 were parasitised, and that of these, in 525 cases the parasite was a Braconid. In 1911 Pierce and Hunter began experiments on the rearing and distributing of the parasites but I am not aware whether a report on these has yet been published.

As to the possibility of using *B. hylobii* in combating *H. abietis*, I have not yet obtained a sufficient knowledge of the former's life-history to make any definite statement, but such observations as I have been able to make lead me to believe there are no special difficulties to overcome. If *B. hylobii* is fairly or reasonably common, and there is no reason to suppose it otherwise, there should be little difficulty in obtaining batches of its cocoons, or numbers of its larvae to breed from. The larvae of *Hylobius*, too, can readily be kept alive if they are not removed from the roots on which they are feeding. I have reared several weevils by removing the smaller roots containing their larvae and keeping these sufficiently moist. The parasite itself is easily reared inasmuch as I bred one batch in an ordinary collecting tube in which I placed a weevil grub as food.

Out of about 70 cocoons, I have obtained no hyperparasites on the Braconid. This again is favourable. The parasite too is evidently hardy. The plantation from which my specimens were obtained is a bleak hillside near the coast and over 600 feet above sea-level. It is often swept by cold North and East winds.

Another interesting fact is that *B. hylobii* attacks the weevil larva in its resting stage, at a time when the latter is practically inactive.

The greater increase in numbers of the parasite as compared with the weevil is also interesting. Every weevil grub attacked gives rise to at least five adult parasites. Of these according to Nordlinger's figures, 90 per cent. will be females, but from my own observations 60 per cent. is a more probable relation.

Assuming that every weevil grub parasitised gives rise to five adults, three of which are females, and that as in the present instance, 30 per cent. of the weevil grubs are attacked in the winter 1913–14, then out of 100 weevil grubs we should get 70 *Hylobius* adults and 90 female Braconids in spring 1914. If we assume further that the rate of increase of *Hylobius* and of *Bracon* in a given year is the same, say

ten, and that the proportion of males to females in the two insects is the same, then we should have in the winter 1914–15, 420 weevil grubs and 540 Braconid. This would, therefore, entail the complete destruction of the weevil. These figures are of course purely hypothetical. Now it is by no means improbable that the Braconid is more prolific than the weevil, and also that the proportion of females to males in the Braconid is greater than in the weevil. These, however, are points which must be cleared up before the practical value of *Bracon hylobii* as a factor in controlling *Hylobius* can be fully demonstrated.

OBSERVATIONS ON THE LIFE-HISTORY OF THE AMERICAN GOOSEBERRY-MILDEW (*SPHAEROTHECA MORS-UVAE* (SCHWEIN.) BERK.[1]

By E. S. SALMON, F.L.S.,

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The rule among the species of the *Erysiphaceae*—to which the American gooseberry-mildew belongs—is a life-cycle consisting of the production of a *conidial* stage during the growing-period of the host-plant, and the production before the advent of winter of a *perithecial* stage. In the *conidial* stage the spore is a naked, short-lived *conidium*; in the *perithecial* stage the spore is an *ascospore* which remains living for several months within the *ascus* inside the thick-walled *perithecium*.

While this is the usual life-cycle, some striking exceptions occur, particularly in cases where a species has found its way into a new continent.

When the vine-mildew (*Uncinula necator* (Schwein.) Burr.) invaded Europe, no *perithecial* stage was found associated with it for the first 47 years[2], the mildew existing during winter in the *conidial* stage in a more or less dormant condition. Appel has shown that before winter patches of hibernating mycelium are found on the stem of the vine; these produce *conidia* the next season. These hibernating patches have thicker-walled hyphae, and more numerous and larger haustoria. Although the perithecial stage of *U. necator* has been found within recent years on a few occasions in different years in France, Germany, and elsewhere, it appears that the production of *perithecia*—which are formed abundantly in America, the native home of this mildew—only takes place *exceptionally* in Europe—possibly under abnormal weather conditions.

[1] Paper read at the Meeting of the Association of Economic Biologists, on April 17, 1914.

[2] Salmon, E. S. A Monograph of the *Erysiphaceae* (*Mem. Torrey Bot. Club*, IX, 1900).

A very similar case is that of the oak mildew. About 10 years ago oak " scrub," and to some extent oak trees also, in England and in many parts of the Continent, became for the first time attacked by a species of the *Erysiphaceae* in the *conidial* stage. It received many names (*e.g. Oidium alphitoides, O. quercinum*, etc.) at the hands of mycologists belonging to that class which has sufficient time only to add to synonymy. In 1911, the discovery in France of the perithecial stage of this mildew on some autumnal shoots of the oak, proved its identity with an endemic American form of *Microsphaera alni* (Wallr.) Salm., which occurs commonly on species of *Quercus* in the United States. Here, again, quite exceptional seasonal conditions would seem to be necessary for the formation of the perithecial stage of this mildew when introduced—as presumably has been the case—into Europe from America. No perithecia have been found in this country and certainly as a general rule the oak-mildew passes the winter in the conidial stage in a more or less dormant condition.

A third case is the mildew which attacks the foliage of that very useful ornamental shrub *Euonymus japonicus*. This mildew first appeared in England, and also on the Continent, about 15 years ago, and only the *conidial* stage is known[1]. It is possible that it is a form of *Erysiphe Polygoni* endemic to Japan on *Euonymus japonicus*, and that it has been imported with that shrub from Japan into Europe. The mildew exists in Europe during the winter months on the evergreen leaves in dormant or nearly dormant hibernating mycelial patches, which on the advent of a warm spell of weather soon produce *conidia*.

What now are the facts with regard to the life-cycle of the American gooseberry-mildew (*Sphaerotheca mors-uvae* (Schwein.) Berk.) in this country, since its introduction into Europe from America about 1900 ? Has its normal life-cycle been interfered with in any way as the result of new factors such as change of climate or different " constitutional " characters of its host-plants ? There is, I think, some reason for thinking that it has. There is no evidence that there is any hibernation of the conidial stage. The perithecial stage—or at least the outward signs of it—is formed abundantly on the surface of the young shoots of the gooseberry. It has been assumed from the first—and quite rightly so under the circumstances—that the continuance from year to year of this new and most destructive pest was everywhere ensured by this abundant production of the perithecial stage. Some facts which I have

[1] Salmon, E. S. Fungus Disease of *Euonymus japonicus* (*Journ. Roy. Hort. Soc.*, XXIX, p. 434 (1905)).

lately observed, however, show the necessity for close investigations to be made to ascertain to what extent the perithecial stage which is formed at different times during any one season remains living through the following winter and is the cause of the first spring outbreaks. The facts lately observed would seem to show that there is a real danger—if the American Gooseberry-mildew Orders are carried out by officials without the guidance of a mycologist—of fruit-growers being prosecuted and fined for not removing from gooseberry bushes *the mildew in a dead condition.*

In August last year, and during the present spring, I have observed the various details connected with the dehiscence of the ripe perithecium and the discharge of the ascospores—a process which I have not before succeeded in observing and one which, I believe, has escaped other investigators. The details will be described in the next number of the *Journal of Agricultural Science* (now in the press[1]). The dehiscence of the ripe perithecium was observed to take place in material collected last August, a few hours after the perithecia had been supplied with moisture; similar material collected in November last and kept dry in the laboratory through the winter, proved when examined in February, March, and April, to be alive, the perithecia dehiscing when supplied with moisture. The dehiscence, which occurred either almost at once—the shortest time being $1\frac{1}{2}$ hours—or after an "incubation" period of several days—took place at temperatures from about 5° C. to 27° C.

This living material was useful in affording a comparison with examples of the perithecial stage obtained from bushes in the open in the spring, *i.e.* after it had "wintered." In all cases, so far, such "over wintered" material, which has been obtained from N., Mid., and E. Kent[2], proved in February or later, to be dead. In such material the perithecium on being pressed open usually exudes drops of an oily nature; the ascus is not turgid, and is often more or less crumpled; the ascospores are filled with some oily material, staining pink with alkannin. No development can be induced on "incubation" at those temperatures which cause living perithecia to dehisce and discharge their spores, and it is clear that such perithecia are dead.

It seems clear, therefore, that some amount of the perithecial stage of the American gooseberry-mildew which is produced in this country either does not reach maturity or does not survive the winter.

[1] Salmon, E. S. Observations on the Perithecial Stage of the American Gooseberry-mildew (*Journ. Agric. Sci.*, VI, p. 187, May, 1914).

[2] Most of this material was kindly sent to me by Mr F. G. Cousins, Inspector for American gooseberry-mildew for Kent.

It is possible, but I think very unlikely, that in these cases where an examination in the spring showed only perithecia with dead asci that all the mature (living) perithecia had fallen previously to the ground. It seems far more probable that this material had never reached that stage of development at which the perithecia can remain alive through the winter. If so, the reason for this failure to mature may be due to the influence of new factors which the mildew encounters in this country —such as the "constitutional" characters of European varieties of gooseberries, or to the weather conditions obtaining in this country in the late summer or autumn. It may possibly prove to be the case that it is only the perithecial stage which is formed early in the season, reaching maturity about July or August, that is really dangerous, and that later-developed perithecia do not survive the winter.

It would of course be unwise to generalise from observations made so far on material obtained in one season only; but there seems clear evidence that both the fruit-grower and the official administrators of the American Gooseberry-mildew Orders have a new fact to reckon with, viz. the natural death, before the spring, of some amount of the perithecial stage of the American gooseberry-mildew.

Postscript. Since the above was written, I have had the opportunity of examining further "over wintered" material of *S. mors-uvae* collected at the end of April and during May.

The first lot of material collected at the end of April, was kindly obtained for me by Mr Gibson (Inspector for American Gooseberry-mildew for Surrey) from Farnham, Newdigate, and Witley. Thirty-four shoots bearing patches of the perithecial stage were sent; these were all closely examined. Twenty-two shoots bore patches of deep-brown persistent mycelium, which on examination proved to be either quite barren with no perithecia, or with just a few (dead) perithecia. The appearance of the barren patches suggested that no perithecia had ever been formed (*i.e.* that the development of the winter stage had been stopped), and not that the perithecia had fallen out from them, since the densely interwoven mycelial patches showed—in many cases at all events—no signs of having been worn thin or disintegrated under the action of weather conditions; in a few cases the mycelial patches may have been partly worn away as the result of "weathering." On more than 50 per cent. of these diseased shoots there was a completely barren, although dark brown, mycelium.

In the remaining twelve examples perithecia had been produced abundantly on the shoots, but in no case was a living ascus found inside

any perithecium. In several cases the perithecia had apparently never reached full development, since the ascus was not the normal size; in those cases where a full-sized ascus was present, it was without exception shrunken and obviously dead, and the ascospores, which contained oil drops, were evidently undergoing a process of degeneration.

On May 4 a commercial gooseberry plantation of "Berry's Early" near Rodmersham, Kent, was visited at a time when the American gooseberry-mildew was just beginning to appear for the first time this season. A number of bushes were found with the (conidial) "summer-stage" of the mildew developing—mostly on the young, green berries. In a considerable number of cases—perhaps in the majority of cases—the affected berries were in close proximity to portions of last year's shoots which were badly infested with the ("over wintered") perithecial stage. On microscopical examination, however, of nine of these shoots —*i.e.* where mildewed berries occurred close to the winter-stage formed in 1913—all the perithecia appeared to be dead, the ascus being either shrivelled or empty, or when containing ascospores the ascus was not turgid, and the spores were full of oily degeneration-products. The perithecium on being pressed open usually exuded drops of some oily substance.

On other branches of the bushes which bore the mildewed berries, and also on other adjoining bushes where no mildew occurred yet, the perithecial stage of 1913 could be found not uncommonly on some of the young shoots (although all the bushes had been "gone over" twice in the process of "tipping"). As in the above-noted cases, the perithecial stage consisted of the dark brown persistent mycelium, often considerably worn away by "weathering," and hundreds of closely aggregated perithecia. Thirty-two of these shoots with the perithecial stage were examined and not one perithecium could be found with a living ascus. The experiment was made of incubating some of this material at 27° C. but no change resulted.

On May 6 a commercial plantation of "Cousin's Seedling," near Sandwich, Kent, was visited. This plantation was so virulently attacked by the mildew in 1913 that practically all the young shoots on every bush became infested with the perithecial stage, and this also was developed on nearly every berry—the whole crop was lost, not a single berry being fit to pick. An examination on May 6 showed that the disease was just re-starting for the season; from 40 % to 50 % of the bushes (250 in number) bore a few berries with small patches of the (conidial) "summer-stage" on them. In a few cases young shoots more or less plentifully infested with the perithecial stage of 1913 were

closely adjacent to these mildewed berries. Nine of these shoots were microscopically examined, but no perithecium containing a living ascus was found. In the majority of cases the ascus was empty and shrivelled; in the few cases where ascospores occurred, the ascus was not turgid, and the spores were full of oily contents and evidently undergoing a process of degeneration. In a very few cases the perithecium contained the spores of the parasitic fungus *Ampelomyces quisqualis* (*Cicinnobolus Cesatii*), but it was clear that the mildew had not been parasitised to any appreciable extent. With regard to the bushes generally, the mildewed berries were found either on branches from which all the young wood (which had probably been diseased) had been cut away, or on spurs on quite old wood.

Since there is no evidence that in these cases these primary infections had been caused by ascospores from the "over wintered" material still present on some of the shoots, the explanation must be looked for in another direction. There are two ways by which infection by ascospores could have occurred. As I have pointed out[1], perithecia may begin to fall to the ground in August from infested berries and, to a less extent, from infested shoots. With regard to this particular plantation, all the berries (as noted above) became very badly infested; they were not removed by the grower until late in August—by which time not only must thousands of perithecia have fallen to the ground, but many of the infested berries had fallen or been scattered by birds; there must therefore have been a heavy infestation of the soil. If, however, the primary infections which were taking place in May had been caused by ascospores arising from the soil, one would have expected to find the majority of the mildewed berries on the lower branches of the bush, *which was certainly not the case; the infected berries being nearly always on the upper branches.*

The second way by which infection could have been caused is as follows. The "tipping," *i.e.* the removal of the infested shoots, was not done until the end of October or beginning of November; by this time a considerable mass of perithecia must have dropped from the perithecial patches. Many of these perithecia would doubtless lodge in the crevices of the bark, or between the bud-scales, etc., and assuming that these perithecia were mature ones capable of remaining dormant through the winter, these would on liberating their ascospores infect the adjacent berries. This theory, to which on the whole I incline, would account for the fact that the berries in the upper part of the bush were first attacked.

[1] *Journ. Agric. Sci.*, VI, p. 187 (1914).

POTATO DISEASES.

By A. S. HORNE.

Over seventy years have elapsed since C. E. P. von Martius[1] set to work to investigate potato disease in Germany and M. J. Berkeley[2] began his observations on the potato murrain, contributed to the *Journal of the Royal Horticultural Society* in 1846. These early observers recognised that potato disease consisted of several distinct maladies some of which they attributed to fungal organisms, but their knowledge of the diseases and fungi was of necessity incomplete. Von Martius noticed several diseases, notably Stockfäule (gangrène sèche or dry-rot), considered to be due to one of the Mucidineae—*Fusisporium solani*; Kräuselkrankheit (la frisole or curl), and Rände (gale), prevalent in the calcareous lands of Thuringia, Bavaria and in Austria. Payen[3] records in 1853 that *Rhizoctonia violacea*, the cause of the disease known in France as mort du safron of the lucerne and sanfoin, could also attack the potato.

The disease known in France as the maladie de la pomme de terre, in Britain as the potato murrain, was regarded by Montagne, Morren, Berkeley, Lindley, Payen and others as due to the fungus *Botrytis infestans* known later as *Phytophthora infestans*. The means of combatting the malady adopted in Payen's time were attention to the soil and drainage, the choice of varieties that appeared to have the best chance of escaping the disease, in the preparation of tubers to be used as seed—tubers to be planted should be exposed to dry air and light for some days before planting, whilst a wash of copper sulphate solution similar to that used for grain at that time was recommended—the rotation of crops, and the effect of autumnal planting was studied. It remained for De Bary (1861—1876) to present the first clear account of the life-history of *Botrytis infestans* and to finally settle its position among

[1] C. E. P. von Martius in *Die Kartoffel Epidemie der letzen Jahre oder die Stockfäule und Rände der Kartoffeln* 1842.

[2] M. J. Berkeley in *Journal of the Royal Hort. Soc.*, I, p. 9 (1846).

[3] Payen in *Des Maladies des pommes de terre*, Paris, 1853.

fungi. About the year 1885 the remedy bouillie bordelaise—bordeaux mixture—used in the first instance and chiefly owing to the efforts of Millardet, to combat the vine mildew in France, was adopted for other plants and amongst others the potato. Under the name Stockfäule (gangrène sèche), Martius probably confused the dry-rot disease, now known to be due to Fusarium, and the old potato disease or murrain caused by *Phytophthora infestans*. This is not surprising since Fusarium rot almost invariably supervenes after the attack by Phytophthora. Kräuselkrankheit, frisole or curl corresponds to the modern Blattrollkrankheit or leaf-roll, but the name Kräuselkrankheit appears to be now used more frequently for a type of curl with crinkled leaves. Curl is a disease of very long standing on the mainland of Europe and in this island but it has caused much consternation on the Continent during the last decade and has recently become a new potato problem for investigators in the United States. Records of its occurrence in Britain are to be found in the memoirs of the Caledonian Horticultural Society[1] of one hundred years ago. The gale, or canker disease as it should now be styled, is still prevalent in Europe and has been detected recently in South Africa[2] on potatoes forwarded to Rhodesia from Britain, and in America. The true nature of the canker organism, *Spongospora solani*, was established by Brunchorst[3] in 1886.

The most important additions to the list of British potato diseases since Berkeley's time are the maladies known as tumour and sprain.

The occurrence of tumour in Britain can be traced back as far as 1878 but the cause of the disease was not known until 1896, when an intracellular parasite was discovered by Schilberszky in material said to have been received from Upper Hungary and named by him *Chrysophlyctis endobiotica*. Chrysophlyctis was thrice described within the space of a few weeks in England in 1902, was chronicled as a Shropshire scourge in 1908 and scheduled under the Destructive Insects and Pests Act of 1907 in the same year.

Sprain, recorded by Frank[4] under the name Buntwerden or Eisenfleckigkeit in the list of diseases enumerated by him in *Kampfbuch* in 1897, and only recently definitely separated as an entity from the tangle of things insufficiently understood, is in all probability of long standing in Great Britain.

[1] Thomas Dickson in *Mem. Caled. Hort. Soc.*, I (1814).

[2] J. B. Pole-Evans in *Trans. Dept. Agric. Farmer's Bull.*, No. 110 (1910).

[3] J. Brunchorst in *Bergens Museums Aarsberetning* (1886).

[4] Frank in *Kampfbuch gegen die Schädlinge unserer Feldfrüchte* (1897).

Various bacterial diseases of the potato have been described during the last twenty-five years. In 1890 Prillieux and Delacroix[1] recorded a bacterial disease attacking the stem of the potato. Other bacterial maladies were subsequently described by Erwin F. Smith[2] in the United States (1896); Iwanoff[3], in Russia (1899); Harrison[4], in Canada (1906) and by Miss Dale[5] (1912). The disease known as black-leg or Schwarzbeinigkeit, which is of sporadic occurrence in Great Britain, has been attributed to various bacteria by different investigators. Frank[6] isolated a bacterium which he called *Micrococcus phytophthorus* (1899); Appel[7] (1902 and 1904), *Bacillus phytophthorus*, which is possibly identical with Frank's organism; C. J. J. van Hall[8], in Holland (1902), *B. atrosepticus*; Pethybridge and Murphy[9], in Ireland (1911), *Bacillus melanogenes*. Harrison's disease possibly belongs to this group.

On the American continent considerable attention is being given to two comparatively recently described fungal diseases—potato wilt, due to *Fusarium oxysporium*, described by Erwin F. Smith and Deane B. Swingle[10] in 1904, which is widespread in America, but, according to W. A. Orton[11], absent from Europe; and Verticillium wilt, due to *Verticillium alboatrum*, described by Reinke and Berthold[12] in 1879, present in America and Europe. Verticillium wilt has recently been recorded in Ireland by Pethybridge[13].

Potato collar-rot caused by the Basidiomycete, *Hypochmis solani* Prill. and Del. occasionally occurs in Britain.

The problem of potato scab has become an increasingly important one in the United States. The American scab is said to be caused by an organism isolated by Thaxter[14] (1890) who named it *Oospora scabies*

[1] Prillieux and Delacroix in *Comptes rend.*, CXI (1890), p. 208.

[2] Erwin F. Smith in *U.S. Dept. Agric. Div. Plant Path. Bull.*, 12 (1896).

[3] Iwanoff in *Zeitschr. f. Pflanzenkrankheiten*, IX (1899), p. 129.

[4] Harrison in *Centralblatt für Bakt.*, II, Abt. XVII (1906), p. 34.

[5] Elizabeth Dale in *Annals of Botany*, XXVI (1912), p. 133.

[6] Frank in *Centralblatt für Bakt.*, II, Abt. V (1899), p. 98.

[7] Appel in *Arb. a. d. biol. Abt. a. Kais. Gesund*, II (1902), p. 373; III (1904).

[8] C. J. J. van Hall in *Bijdragen tot de Kennis der bakterieelle Plantenziekten*, Diss., Amsterdam (1902).

[9] Pethybridge and Murphy in *Proc. Roy. Acad.* XXIX, sec. B, No. 1 (1911).

[10] Erwin F. Smith and Deane B. Swingle. *U.S. Dept. Agric. Bur. Pl. Ind. Bull.*, 55 (1904).

[11] W. A. Orton in *U.S. Dept. Agric. Bur. Pl. Ind. Bull.*, 64 (1914).

[12] J. Reinke and G. Berthold. *Die Zersetzung der Kartoffel durch Pilze.* Berlin (1879).

[13] G. H. Pethybridge in *Jour. Dept. Agric. and Tech. Instruc. Ireland*, XIII, No. 3 (1913), p. 23.

[14] R. Thaxter in *Conn. Agr. Expt. Sta. Rept.* (1890), p. 81.

(Mucidineae), but G. C. Cunningham[1] (1912) suggests its transference to the genus Streptothrix (Schizomycetes) and H. T. Güssow[2] refers it to Actinomyces. B. F. Lutman[3] (1913) has described the pathological anatomy of this scab. To what extent the British scab is due to *Oospora scabies* has yet to be determined.

A disease recently described by the writer[4] and named bruise, owing to the occurrence of greyish or black areas in the flesh of potato tubers which renders them unfit for culinary purposes, appears to be of a physiological nature and is perhaps often occasioned by growing potatoes in poor or insufficiently cultivated land.

Besides the fungal and physiological maladies, there are of course several pests on the animal side. The Colorado beetle scourge of the United States is fortunately not prevalent in these islands. The tuber-boring wire-worm, however, is frequently troublesome. The very much neglected subject of insects injurious to the potato foliage has been recently studied by Professor H. Maxwell Lefroy and the writer and the results obtained will be soon communicated to these Annals.

I propose now to consider as far as possible in correct perspective only those problems, the insect question excepted, that are of considerable economic importance at the present time in Great Britain.

Tumour.

The disease caused by *Chrysophlyctis endobiotica*—the tumour organism—has claimed considerable attention during the last few years, firstly owing to reports of an alarming kind relative to the virulence of this parasite and fear lest it might spread and eventually ruin the potato-growing industry ; and secondly, owing to the stringent measures taken by other countries, alarmed by reports of the prevalence of the disease here, against the importation of British-grown potatoes. According to the Report[5] issued by the Intelligence Division of the Board of Agriculture and Fisheries, 1911–1912, the actual loss occasioned to the potato harvest here is very slight indeed, since the report states : "There are probably scarcely five hundred acres in all England which are under cultivation for potatoes as a field crop which are liable to be affected while even in these the proportion of diseased tubers is

[1] G. C. Cunningham in *Phytopathology*, II (1912).
[2] H. T. Güssow in paper read before *Assoc. Econ. Biol.* London. (Easter, 1914.)
[3] B. F. Lutman in *Phytopathology*, III (1913), p. 255.
[4] A. S. Horne in *Jour. Roy. Hort. Soc.* XXXVIII, p. 40.
[5] Board of Agric. and Fish. *Annual Rept. Intellig. Div.*, Pt. II (1913), p. 24.

generally trifling." Owing to the regulations adopted by other Governments, however, the indirect loss to potato-growers is very considerable.

The question of the degree of virulence possessed by this organism needs searching analysis and the following points may be enumerated in this connection :

(1) Tubers planted in experimentally infected soil have produced without fail plants bearing diseased tubers (M. C. Potter).

(2) Diseased tubers have been produced year after year, irrespective of the kind of season, in soil once infected (M. C. Potter).

(3) Several varieties of potato were affected when planted in Potter's experimentally infected soil.

(4) The Report issued by the Intelligence Division, 1911–1912, states that in spite of the exceptionally dry season in 1911, the disease in all the badly affected places was as manifest as ever even though it was not observed in the less badly attacked districts.

(5) According to the Report, some varieties are practically immune to Chrysophlyctis.

It may be gathered from the Report that the disease is largely confined to cottage and allotment gardens. Now in gardens of this type, frequently ill-kept, where potatoes are grown year after year without rotation, *canker* also exhibits its worst form, rendering potatoes worthless and unsightly (see *Journal of the Royal Horticultural Society*, vol. XXXVII, figs. 101, 102). Is Chrysophlyctis, in this country, really more virulent in character than the canker parasite, *Spongospora solani*, or is the supposed greater virulence merely apparent owing to the absence of sufficient information on the canker side ?

The life-history of Chrysophlyctis is moderately well known, nevertheless several important problems remain to be solved, such as (1) the exact nature of the bodies penetrating the tissue and the method of penetration ; (2) the mode of existence for a prolonged period in the soil ; (3) the conditions which favour or inhibit infection.

It is known that the fungus forms resting bodies (sporangia) in the tubers which when returned to the soil are capable of passing the winter there and may perhaps rest for years in the soil without losing the power to germinate. These sporangia are therefore a prolific source of infection and it is important to realise that infection can be brought about by their means in the following ways :

1. By planting diseased tubers.
2. By planting not-diseased tubers removed from infected soil.

3. By planting not-diseased tubers that have been in contact with diseased or not-diseased tubers from an infected soil.

4. By transference of soil from an infected area by some means or other, even though actual disease be not present in that area.

Every possible precaution should of course be taken to prevent the dissemination of these infective bodies, and the destruction of all diseased material is a reasonable and sound requirement.

Questions naturally arise as to how the disease can be fought *in situ* and the following issues need urgent attention:

1. The possibility of devising some treatment for sound tubers raised on infected soils.

2. The experimental treatment of infected soils.

3. Extended experimental work with varieties possibly immune.

The subject of resistance to Chrysophlyctis is an extremely important one. A high degree of resistance for certain varieties is claimed in the Report issued by the Intelligence Division and it is stated therein that the varieties when planted on infected land in several districts proved highly resistant. This matter needs keen attention under more searching experimental conditions in different localities and seasons.

The Phytophthora problem.

Although *Phytophthora infestans* is still the cause of the greatest financial loss through actual damage to the potato harvest in Great Britain, and in spite of the mass of literature that has arisen in connection with this subject, several important matters still need urgent attention. Of these, the manner in which the infection of the potato crop is occasioned each year, will be first considered.

Marshall Ward[1] held the view, by analogy with the behaviour of many rust fungi, that the mycelium of the fungus could remain dormant in the tuber through the winter and bring about infection in the following season:

"More commonly however the tubers are beginning to ripen when the hyphae reach them and the mycelium goes to sleep—passes into a dormant state—between the cells of the ripening tuber."

The expression "dormant mycelium" is not necessarily restricted to mean mycelium hibernating in tubers showing disease, but admits the presence of mycelium in healthy tubers. Hence Marshall Ward

[1] H. Marshall Ward in *Diseases of Plants*, p. 75.

advised that potatoes should never be saved for seed from plants of a diseased crop.

Massee[1] adopted and elaborated this theory claiming that outbreaks of Phytophthora and epidemics over wide areas are due to hibernating mycelium. He was led to the peculiar view of the wholesale migration of mycelium from the parent tuber to its own offspring:

"The great bulk of disease is due to hibernating mycelium against which no remedy is known." "I have proved by repeated experiments that when a diseased tuber is planted, the mycelium from such tuber passes into the young potatoes which also become diseased."

"The produce of a diseased tuber is always diseased." "Potatoes from a crop known to be diseased should never be used for seed."

These authors were committed to a most pessimistic outlook upon the whole problem.

Now as a matter of fact, sections of healthy tubers invariably fail to show the mycelium of Phytophthora in its accustomed place—the air spaces—whilst microtome preparations through the junction of diseased and healthy tissue, show that the mycelium present in the diseased portion ceases at the boundary line between the two. The question of dormant mycelium in the sense used by Marshall Ward, therefore, passes beyond the pale of argument or controversy. The conclusion is reached that the disease is not carried by entirely healthy tubers unless the mycelium reside saprophytically in the skin, and of this there exists no positive evidence. Attention should therefore be concentrated upon diseased tubers no matter how slightly diseased, as a means of causing an epidemic. The first question that naturally arises is this, can the mycelium present in diseased tubers maintain itself through the winter until the planting season begins? Pethybridge states definitely that it can and the writer can confirm his statement so that a positive answer must be returned. Secondly, does this fact explain the infection of crops each season? Upon planting diseased tubers the fungus might be returned in a living condition to the soil and remain there to infect the young tubers, but no evidence has been obtained on this point. On the other hand, the fungus might pass from the planted tubers to the young shoot. The evidence available in this connection leaves much to be desired.

Massee[2] claims to have found Phytophthora present upon shoots originating from diseased sets presumed to contain this fungus.

[1] G. Massee in *Diseases of Cultivated Plants and Trees*, p. 125.

[2] G. Massee in *Kew Bull.*, 4 (1906).

Pethybridge[1] found that one plant out of nine raised from diseased sets, planted in a cool greenhouse " produced a shoot only 2 or 3 inches high which quickly became diseased from below upwards and soon died. Doubtless the mycelium had entered the shoot from the parent set." The plant was removed but Phytophthora was subsequently detected on several plants in this house. Pethybridge states " although absolute proof is lacking, it seems practically certain that the plants whose foliage became diseased must have become infected by means of ' spores ' from the single diseased sprout sent above ground by one of the diseased sets." It is not made evident from the description that Phytophthora had been actually observed upon this single diseased shoot and its upward course from the tuber traced, so that the experiment as described does not demonstrate that the fungus developed with the developing sprout. This important point still needs to be settled and evidence obtained from experiments in greenhouses would need to be supported by evidence from extensive field experiments.

That diseased tubers may produce healthy plants is a matter of common knowledge. The crucial question in relation to the infection of crops is whether and, if so, in what proportion, will diseased tubers yield diseased plants. A single diseased plant as everyone knows becomes a centre of infection and the possible source of an epidemic, since the fungus possesses the power of rapid growth, rapid sporulation and the spores are rapidly disseminated. It is important to realise that a single diseased plant in, say, a twenty-acre field of potatoes might start an epidemic. What then are the chances for, or against, the occurrence of one bad plant in a twenty-acre field ? Results which show complete failure to obtain Phytophthora in the aerial parts produced by diseased potatoes must be received with some reserve, owing to the small number of tubers planted and since information is usually lacking as to whether the fungus was actually observed or demonstrated to be living or even present in the tubers when planted.

There are of course other possible methods whereby an outbreak in spring might be occasioned but these have either no positive evidence in favour of them or they have not yet been investigated.

Payen[2] in 1853 records that he had observed *Botrytis infestans* on the tomato and since Payen's time the fungus has also been recorded as occurring upon various wild Solanums. According to Howard S.

[1] G. H. Pethybridge in *Sci. Proc. Roy. Dub. Soc.*, XIII (N.S.), No. 2 (1911), p. 21.

[2] Payen in *Des maladies des pommes de terre.* Paris (1853).

Reed[1] (1912) the Phytophthora of tomato is identical with that of the potato. The formation of conidia upon hosts other than the potato may therefore prove to be a source of infection and the cause of an epidemic.

A very attractive solution appeared to be in the possible discovery of and wide occurrence of sexually-formed resting spores such as occur in the related fungus Pythium. Oospores of Phytophthora are now known, and chiefly owing to the work of Clinton[2] who obtained them, in pure cultures of the fungus in artificial media. In spite of diligent and persistent search by numerous investigators, oospores, however, have not yet been discovered within or upon the potato plant so that they do not appear to be formed upon this particular host. There seems to be no reason, of course, why oospores should not be found upon some other host and be discharged to the soil from the host, but no extensive study in this connection has yet been made.

Another point that needs to be determined is whether the mycelium of Phytophthora can maintain existence in the soil from the autumn until the following potato-growing season, either parasitically in the many small potatoes remaining in the soil or saprophytically in fragments of tuber and pieces of skin.

Another phase of the Phytophthora problem must now be considered—the actual occurrence and mode of occurrence of the disease.

Infection of the foliage may be brought about in two ways. Firstly, the mycelium present in a planted diseased tuber might extend into the growing sprout and thence into the leaves and infect them. Secondly, the leaves might be directly infected by means of conidia, wind borne or brought by some other means. In this case the zoospores liberated from the conidia germinate forming mycelium which enters the tissue of the leaf and causes it to droop and die. Spraying when properly performed has been found an efficient remedy against the premature death of the foliage; the disease is checked and the growth of the plant is actually stimulated.

Tuber infection also may be brought about in two ways. Firstly, in the case of plants with infected foliage the mycelium could extend into and along the vascular bundles ultimately reaching the growing tubers, but this method does not appear to be of frequent occurrence. Secondly, the growing tubers might be attacked directly from the soil. Irrefutable evidence of the frequent occurrence of this mode of infection

[1] Howard S. Reed in *Phyt.* II. (1912), p. 250.

[2] G. P. Clinton in *Science*, N.S. XXXIV (1911), p. 744.

may be obtained by scanning diseased tubers in the field when they are lifted. In such cases the following points furnish a guide : (1) the stalk-end of the tuber when cut across may be entirely without discolouration, (2) the brown marks in the flesh of the tuber caused by the fungus, frequently do not extend from the skin as far inward as the principal cylinder of vascular bundles, (3) the brown shallow areas of diseased tissue near the skin are often quite isolated and sometimes limited to the neighbourhood of an eye.

The subterranean attack might be occasioned by :

(1) Mycelium, if it exists.
(2) Oospores, if they exist.
(3) Zoospores.

1 2

Fig. 1. External view of tuber attacked by Phytophthora from the soil.
Fig. 2. Healthy tuber with clean skin for comparison with Fig. 1.

As already stated no evidence has yet been obtained relating to the presence of mycelium or oospores in the soil. With regard to zoospores, it may be fairly reasoned that if the foliage is attacked, the conidia formed on the leaves can be carried by the wind and distributed not only to neighbouring plants but on the surface of the soil. During a period of heavy rain the conidia or zoospores would be carried into the soil and eventually reach the surface of the tuber and penetrate it. This matter still needs adequate experimental proof.

One of the chief puzzles afforded by the Phytophthora problem is afforded by the case of field crops which are badly diseased when lifted

although no disease had been detected in the foliage. An instance occurred in 1909, on a large field in Durham County. I observed no Phytophthora on the foliage during the season, but at the lifting, there were very few plants without one or more diseased tubers (Fig. 1). The uniform infection of the field seemed extraordinary. It could be accounted for in three possible ways:

(1) Phytophthora may have been present on the plant, but inconspicuous and escaped observation.

(2) The soil may have become infected with wind-blown conidia from some potato field in a neighbouring farm.

(3) The soil may have been infected with mycelium or oospores, if such do exist in the soil.

Fig. 3. Tuber cut open to show the brown rot caused by Phytophthora.

The whole Phytophthora problem needs very careful study with a view to determining whether there is or is not a definite soil-factor, occasioned by the power of the fungus to rest or live in the soil. If it can be shown that there is not, the prospect of eradicating the disease is not hopeless since effort could be concentrated in the selection of seed tubers and widespread and efficient treatment of the foliage.

A third line of enquiry which relates to the conditions that favour the development of the blight fungus and involves two issues—(1) blighted tubers, (2) blighted foliage—will be pursued in a later paper.

Sprain.

Sprain has caused considerable loss to potato-growers within the last few years, affecting certain varieties in the field crop, often rendering the yield practically unsaleable.

Sprain includes two forms of tuber-disease—blotch (internal disease) and streak (sprain) which have not yet been proved identical. Blotch, under the name internal disease, is reported to have been under investigation by Marshall Ward nearly twenty years ago but I have been informed by Prof. Seward that Marshall Ward left no records of such investigation. The word sprain, as used in the north, is applied to tubers with internal, brown, streak-like markings. This word has been adopted by the Board of Agriculture to include both blotch and streak.

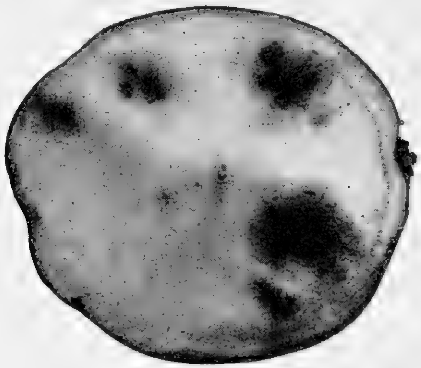

Fig. 4. Section of a tuber showing internal disease or blotch.

Under the name of Buntwerden or Eisenfleckigkeit, sprain has long been known on the continent of Europe and recognised as a distinct disease not caused by fungal organisms. In Britain blotch and streak were supposed by some authors to be either directly or indirectly due to the late blight fungus and by others to the dry rot organisms. These suppositions, however, as the writer[1] has recently shown, cannot be upheld.

The importance of ascertaining whether the disease is caused by an organism from the practical point of view is evident since the question of the infection of crops is involved. Disease might arise from planting diseased tubers or owing to the presence or transference of infected soil. Frank considered that Buntwerden was due to the prevailing conditions of soil and climate but his point of view is founded upon the

[1] A. S. Horne in *Jour. Agric. Science*, III, Pt. 3 (1910).

apparent absence of an organism and insufficient experimental evidence. There are three experimental methods of attacking the problem: (1) that of analysis by means of field experiments, (2) that of attempting to isolate pathogenic bacteria from diseased tubers, (3) that of analysis of the bacterial flora of soils from "sprained" areas. At present only the first of these methods has been seriously adopted by the writer with the following chief results:

(1) In four consecutive years a certain proportion of diseased tubers was obtained in the yield from diseased sets upon every occasion when diseased sets were planted, in Northumberland (1909, 1910), Devonshire (1909–1910), Ireland (planted by Dr Pethybridge, 1910), Chelsea (1911), and Wisley (1912).

(2) In the fifth year at Wisley (1913) no diseased tubers were obtained in the yield from diseased sets.

(3) In 1909 the writer selected disease-free tubers of the Sutton Flourball variety from a sack containing a high percentage of diseased potatoes given to him for experimental purposes by Messrs Sutton. The issue from these selected tubers has proved healthy in each successive year—1909, Northumberland and Devon; 1910, Northumberland, Devon and Ireland; 1911, Chelsea; 1912, Wisley and Walton-on-Thames (in sprained soil); 1913, Wisley.

(4) Disease-free tubers of the susceptible variety, Duke of York obtained from a locality where sprain is absent, yielded a diseased crop when planted upon "sprained" land, at three different stations in Scotland in 1911.

(5) Tubers selected disease-free from the produce raised in Scotland in 1911, yielded only a few diseased tubers at Wisley and none at Oxshott in 1912 and none at Wisley in 1913—but in this season diseased sets produced healthy tubers.

It is clear that "sprain" is influenced a great deal by conditions of soil and weather, but it is by no means certain that it is entirely due to these conditions as Frank supposed. Analyses of soils from different centres where considerable harm had been done to the potato crop by internal disease showed that they were exceptionally poor in phosphates, potash and lime, being moorish, sandy soils, but sprain is by no means confined to such soil, and moreover selected tubers of susceptible varieties when planted experimentally on similar soils have not taken the disease. It is exceedingly difficult to interpret all the evidence entirely on a physiological basis. But the evidence is not at all incompatible with the theory of the existence of an organism-factor—the organism

being of bacterial nature. The apparently conflicting evidence, such as is production of a healthy crop from susceptible varieties upon "sprained" land and the occurrence of healthy issue from diseased tubers, is paralleled among the organism-caused diseases. Thus the potato crop including that obtained from the susceptible varieties may not be appreciably affected by the canker organism although this parasite is actually present in the soil, whilst the production of healthy plants and potatoes from sets affected with Phytophthora is, as I have already stated, of common occurrence. The failure to obtain sprain in the vegetative generations proceeding from tubers originally selected as disease-free from diseased stock of susceptible varieties when planted in soils of several kinds in different localities seems opposed to a purely physiological explanation.

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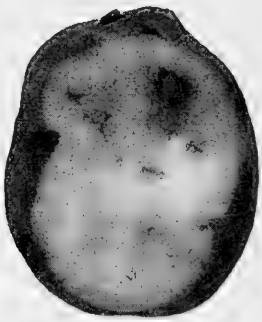

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Fig. 5. Section of a tuber showing sprain or streak.
Fig. 6. Another section of the same tuber.

Pending attempts to isolate pathogenic bacteria, additional evidence might be gained by attempting to infect potatoes with sprain through the agency of soil derived from lands liable to it.

In the meanwhile the best means of preventing loss through sprain will be those which have certainly occurred to skilled potato-growers; firstly, to avoid as far as possible the use of "sprained" tubers for seed, and secondly, to cultivate varieties which are the least susceptible to the disease. The most thorough method of procedure would be to obtain an accurate record of the distribution in Britain of the lands liable to sprain, and to carry out potato trials in different localities where the disease is most troublesome, with the object of discovering the most suitable and relatively sprain-immune varieties for the district about each experimental area.

Fusarium disease.

Two types of Fusarium disease are recognised by Orton[1]. The first, Fusarium wilt, caused by *Fusarium oxysporium* described by Smith and Swingle in 1904, affects the field crop and is one of the most serious diseases of the potato with which the United States has to deal. According to Orton, there is no evidence that the Fusarium wilt occurs in Europe. Wollenweber[2] has been able to differentiate the *Fusarium oxysporium* of Smith and Swingle from other potato Fusaria and finds it to be distinct from any European form. The second or dry rot disease, according to Wollenweber's investigations, appears to be caused by one or more species of Fusarium. The dry rot Fusaria do not, as a rule, attack the tubers when in the soil, although they are certainly present there as shown by Miss Dale[3], who includes *F. solani* in the fungus flora obtained by her from sandy soils. Miss S. Longman[4] records that *Fusarium solani* attacked the potato plant in experimental plots at Reading in 1909, but cases appear to be of rare occurrence in Britain.

Fusarium becomes evident in the potato pit or store especially when potatoes are stored in a damp condition, a state of affairs often difficult to avoid in some potato-growing districts. A crop that has been attacked by Phytophthora or sprain is especially liable to suffer.

The question of the parasitism of *Fusarium solani* was fully discussed by Pethybridge and Bowers[5] in 1908. These authors state it is quite clear that the fungus is a true parasite capable of directly producing the disease in absolutely healthy potato tubers. The disease can be communicated therefore to healthy tubers in contact with diseased ones. A similar conclusion was arrived at by Miss Longman.

Curl.

"This disease, so far as I can learn, first began to be alarming to the growers of the potato, about thirty-five or forty years ago. Since that time, it has continued to engage the attention of many eminent agriculturists and gardeners"—Thomas Dickson, 6th March, 1810, in *Mem. Caled. Hort. Soc.* I (1814).

[1] W. A. Orton in *U.S. Dept. Agric. Bur. Pl. Ind. Bull.*, No. 64 (1914).
[2] H. W. Wollenweber in *Phytopathology*, v. 3, No. 1 (1913).
[3] Elizabeth Dale in *Ann. Myc.* X, No. 5 (1912), p. 471.
[4] Sibyl Longman in *Jour. Linn. Soc. Bot.*, XXXIX (1909).
[5] G. H. Pethybridge and E. H. Bowers in *Econ. Proc. Roy. Dub. Soc.*, I, Pt. 14 (1908).

" No plant disease in this generation has been the subject of such general discussion as that known in Germany as the ' Blattrollkrankheit ' herein named ' Leaf-roll.' None has aroused greater difference of opinion as to its nature and cause, and no other single malady of plants is to-day receiving so much investigation by skilled pathologists

Fig. 7. Foliage from a plant of the President potato affected with curl showing the under surface of the leaflet exposed owing to the curl, small brown blotches and dead leaflet-ends.

as this. Possibly no disease which has appeared since the advent of *Phytophthora infestans* in the forties presents a greater menace to potato culture "—W. A. Orton, Feb. 10, 1914 in *U.S. Dept. Agric. Bur. Pl. Ind. Bull.*, 64 (1914).

By far the most important case of curl recently recorded in Britain has occurred in connection with the President potato, a variety imported from Germany and Holland on several occasions during the last few years. On land in the neighbourhood of Dunbar, the President yielded an enormous crop—fifteen tons to the acre—and produced only a small percentage of bad plants. But in certain other localities, this variety produced a high percentage of dwarfed plants with foliage of a light green colour or tinged with yellow or pink and leaves rolled upward and frequently much blotched as already described by the writer[1]. Quanjer[2], who has investigated curl in certain varieties in Holland, states that the phloem strands in the stem of leaf-roll plants are shrunken and lignified so that the translocation of food material to the tubers is interfered with. The bad plants produced by the President in Britain produced an exceedingly small yield of very small tubers.

Curl has often been attributed to fungi and notably Fusarium, Verticillium, and Macrosporium. Thus Appel originally believed that it was due to Fusarium and this view obtained for quite a considerable time and is held still by some authorities, notably Köch and Kormanth.

But abundant cases of leaf-roll have been recorded, as already pointed out by Sorauer, including the present case of the President, where no fungi are present. Macrosporium was present in the blotched foliage of the President, in the potato field in 1910, but since blotched foliage of a similar nature was produced in localities where Macrosporium was entirely absent from the plants, the disease could not be attributed to this or any other fungus.

It was next necessary to establish to what extent, if any, the condition of the foliage in bad plants might be brought about by injurious insects. Accordingly a joint enquiry into the subject was instituted by Professor H. Maxwell Lefroy and the writer, and yielded results which show that although the insect factor is of more importance in relation to diseased foliage than has been hitherto supposed, nevertheless this particular malady is not caused by insects.

But considerable light was thrown on the probable nature of the disease during the study of the plants raised from seed of the President for the purpose of insect infestations by Professor Lefroy and the writer at the Royal Horticultural Society's gardens, Wisley (1912–1913–1914), the Chelsea Physic Garden (1911–1912), and at Messrs Sutton's trial grounds, Reading (1912), and evidence was obtained which points

[1] A. S. Horne in *Jour. Roy. Hort. Soc.* XXXVI, p. 618 (1911).

[2] H. M. Quanjer in *Med. van de Rijks Hoogere Land-, Tuinen Bosch.*, Deel VI (1913).

conclusively to the non-parasitic nature of the disease. Hence the question of infection does not occur.

A similar conclusion has been reached by W. A. Orton from a study of leaf-roll in seedling varieties in the United States.

Professor Lefroy and the writer found that the seedling plants used for infestations exhibited considerable variability not only in the habit, shape of leaf, and other external characters but in physiological characters as evidenced by selection by the White Fly (Aleurodes) and by the uneven response exhibited by the plants when under similar experimental conditions. These physiological characters are not in any way associated with particular external plant features. The tubers themselves, as the writer[1] has pointed out, also exhibit considerable variability in shape, kind of eye, and other characters, whilst Doby[2] has recently shown that tubers from plants affected with leaf-roll give a higher reaction with respect to oxidase, peroxidase, and tyrosinase; also they had a slightly higher ash content and less starch and protein.

Taking everything into consideration it is very evident, firstly, that physiological variability plays an important rôle in the curl problem, and secondly, conditions of culture. There appear to be certain optima that favour the production of good plants, as at Dunbar in 1910, below these optima the percentage of bad plants increases. Pathological symptoms are the outward expression of the response made by particular plants to conditions which do not suit them.

The value of selection under the circumstances must now be considered. In the course of recent experiments, at Wisley, small tubers, whether from good or bad plants, produced bad plants as a rule—tubers from bad plants being usually small, produced bad plants. Of greater importance, however, was the result obtained from tubers that had been specially selected as desirable for seed purposes, obtained from the Dunbar ground which produced a heavy crop in 1910. These tubers produced both good and bad plants and a high percentage of the latter. The occurrence of bad plants, however, did not bear any relation to any particular characters of the tubers which produced them. Selection becomes, therefore, an exceedingly difficult matter, since there appear to be no external tuber-characters that can be used as a guide in selecting favourable physiological plant-characters. Selection on the basis of favourable external characters (shallow eyes, etc.) leaves entirely to chance the selection of favourable internal properties.

[1] A. S. Horne in *Jour. Roy. Hort. Soc.*, XXXIX (1914), p. 596.

[2] G. Doby in *Zeit. für Pflanzenkrankheiten*, Bd. XXI, XXII (1911, 1912).

For this reason the percentage of bad plants obtained through a particular stock of the President might be greater than that obtained through the use of another stock and the total yield proportionally less—other conditions being similar.

Canker.

Owing to the serious notice given to potato canker, in a recent Bulletin issued by the United States Department of Agriculture, investigators in Great Britain may be compelled to devote considerable attention to this disease, although as already pointed out by the writer, the worst cases in this country are to be found in ill-kept gardens, whilst comparatively little damage is done to the potato harvest by canker. The tubers in the field crops are sometimes scabby but the scab is often less noticeable than the brown scab of unknown origin prevalent in many parts of the country. I. E. Melhus[1], the author of the United States Bulletin, devotes little attention to the comparatively trivial damage caused by the canker organism in Britain whilst prominence is given to the statements of serious damage to the potatoes in Ireland.

In Ireland canker is reported as causing considerable loss to the potato crop. Johnson[2] states " I have no doubt myself, that this Spongospora scab has a good deal to do with the miserable average yield per acre of potatoes in the west of Ireland. It is in some districts of Ireland as injurious to potatoes as finger-and-toe in Turnips," and Pethybridge[3] writes of the attacks caused by Spongospora, " they were particularly disastrous on those portions of the land which for special purposes have now been cropped for four successive seasons with potatoes, the cankerous form of the disease being extremely common."

Güssow[4] with regard to canker in Canada states " the disease should by no means be regarded lightly. Severe attacks occur when potatoes are planted year after year in infected land." The disease was also regarded seriously by Pole-Evans, in a circular issued by the Transvaal Department of Agriculture in 1910.

Pethybridge and Güssow specially note the occurrence of canker in land that has been cropped year after year for potatoes and it seems clear, from the published accounts of its occurrence in Ireland, that the

[1] I. E. Melhus in *U.S. Dept. Agric. Bur. Pl. Ind. Bull.*, No. 82 (April 6, 1914).

[2] T. Johnson in *Econ. Proc. Roy. Dub. Soc.*, I (1908), p. 453.

[3] G. H. Pethybridge in *Jour. Dept. Africa. Tech. Instruc. Ireland*, XIII, No. 3 (1913), p. 16.

[4] H. T. Güssow in *Phytopathology*, V, 3, No. 1.

disease in its worst form occurs in poor or badly cultivated land and is favoured by the wetness of the season. These points should be borne in mind in attempting to arrive at an estimate of the relative importance of the canker disease from an economic standpoint, and to avoid the danger of unduly exaggerating the danger of canker. It is surely undesirable that the potato industry in Britain should suffer more than absolutely necessary, and that other countries should lose by rejecting British-grown potatoes for seed which still rank amongst the finest in the world.

Fig. 8. Wart stage of potato canker.

Nevertheless the point of view and the attitude of investigators in the United States must receive consideration. Melhus points out that scabbiness is a more serious handicap in the American markets than in those of European countries, and further states that " If powdery scab (canker) should prove no more troublesome in the United States than it

has been up to the present in Europe, it would be rated as a disease of secondary importance as compared with late-blight or with Fusarium wilt. But there are reasons for fearing that it may become more prevalent here....It quite often occurs that introduced parasites are more destructive in a new habitat than in their native environment. Likewise it is not impossible that Spongospora may find the American varieties of potato more susceptible than the European sorts."

The prevalence of canker in many European countries and the Dominion of Canada has prompted the Department of Agriculture in the United States to extend for a time the Quarantine on foreign potatoes. The attitude of the United States in this matter may render it advisable to ascertain the distribution of canker in Britain as in the case of the tumour parasite, but statistics would be difficult to obtain and the process of recording would need to be spread over several years for numerous and obvious reasons.

The symptoms of canker have already been fully described by the writer[1]. The organism *Spongospora solani* Brunchorst, as in the case of Chrysophlyctis, can rest in the soil and there seems little immediate prospect of arriving at a soil remedy. Both organisms form resting bodies which are said to be capable of remaining for many years in the soil, but whether there is any other mode of subterranean existence is as yet quite unknown. Neither is it known exactly how the process of infection is carried out, whilst we are almost entirely ignorant of the conditions that favour or inhibit infection.

Some varieties of potato, which are more susceptible than others in a certain district, in other districts may be almost immune. Therefore generalisations from experiments in one locality only should be avoided and tests established at several experimental stations.

[1] A. S. Horne in *Jour. Roy. Hort. Soc.* XXXVII (1911).

A NOTE ON CELERY LEAF-SPOT DISEASE.

By F. J. CHITTENDEN, F.L.S.

The disease of celery known as leaf-spot, rust, or blight, due to the attack of the fungus *Septoria petroselini* var. *apii* B. and C., has spread with alarming rapidity over this country since it was first definitely recognised here in 1906[1].

An account of the disease and its spread, with notes on the fungus that causes it and its distribution in Europe and America, are given in the Journal of the Royal Horticultural Society[2] and it is there shown that much of the commercial " seed " offered for sale is infected with the fungus. The small black fruits of the fungus appear on the walls of the celery " seeds " and the pieces of stem to which they are attached with considerable frequency and may be readily seen by the aid of a lens. Experimental cultivation from fresh seed proved the contained spores to be viable and Klebahn showed[3] that spraying healthy plants with the washings from affected seeds led to the infection of the plants with the disease.

The author was led to suspect the seed as the principal, if not the only source of infection, by the curious distribution of the earlier attacks, the incidence of the disease on certain strains of celery, the absence of any records of attack upon wild plants, and the fact that so far as enquiry showed, the seeds from which the diseased plants had been raised had been purchased from one or two sources. Against it was the fact that all the earlier attacks had been noticed late in the year, generally from September onwards, though one or two attacks had been seen in July. At this season the disease had obtained such a hold upon the plants that spraying methods proved almost entirely inadequate to prevent its spread and total loss of crop frequently resulted. Later, attacks of a slighter nature were noticed nearer the beginning of the growing season and spraying with Bordeaux mixture at frequent intervals

[1] Chittenden, F. J. *Journal R.H.S.*, XXXII (1907), p. cxii.
[2] Chittenden, F. J. Celery Leaf-Spot, *Journal R.H.S.*, XXXVII (1911), p. 115.
[3] Klebahn, H. Krankheiten des Selleries, *Zeits. f. Pflanzenkr.* (1910), p. 4.

mitigated the severity of the attack[1], and in some cases proved a perfect cure.

When the paper on "Celery Leaf-Spot" appeared we were in possession of the knowledge that the disease was due to the fungus *Septoria petroselini* var. *apii* B. and C., that it was spreading rapidly and in a fashion that could best be explained on the assumption that the seed carried infection, that the "seed[2]" frequently showed the fruits of the fungus, that these fruits contained spores capable of germinating, and that plants sprayed with water containing these spores succumbed to the disease, but the actual infection of the seedlings from infected seeds had not been observed. We have recently been able to demonstrate this infection and to place this on record is the object of this note.

Seed showing the fungus fruits containing spores was sown in the ordinary way and the germination kept under observation. It was found that in many cases the pericarp remained attached to the cotyledons for a considerable time after they emerged from the soil and became green, and that many of the cotyledons turned yellow owing to the attack of the fungus which quickly produced fruit containing the typical spores. Only those seedlings which had grown from seed showing the fungus were attacked at this time and the pieces of pericarp attached to the diseased cotyledons showed the fungus quite clearly. Side by side with the diseased seedlings were others which were at this stage perfectly free from attack and which were developed from healthy seed. The chain of evidence that the seed carries the infection is therefore complete.

Whether there are any other modes by which the fungus maintains its infective powers from season to season, as, *e.g.* on diseased portions of plants thrown on the rubbish heap or dug into the ground, is not clear, but it is clearly a point of economic importance that seed-growers should take every care to save seed only from healthy plants. If this were consistently done the author feels sure it would do much to mitigate the severity of the attacks and it would probably result in stamping out the disease entirely.

The disease appears to spread more slowly during the seedling stage than later in the season and the attack is more localised on the plant. Diseased plants in September usually show the fruits of the fungus

[1] See for instance Salmon, E., in *Gard. Chron.* 1913.

[2] It ought perhaps to be noted that the commercial celery "seed" really consists of fruits or half fruits and therefore carries parts of the parent plant readily open to attack.

dotted very closely over the whole of the diseased leaves which become dull blackish-green in consequence, but the seedlings show, both on cotyledons and on foliage leaves, yellow spots extending to the leaf margin bearing the small black fruits of the fungus, and contrasting markedly with the bright green of the healthy parts of the foliage.

When the matter was first enquired into about 40 % of the commercial " seed " samples examined showed the presence of the fungus, now the percentage has risen to 90 %. The attention of seed-growers and seedsmen in this country has been called to the extent to which the infection has reached, and the danger to the crop from sowing seed containing even a small number of infected " seeds," and it is to be hoped that they will endeavour to produce " seed " free from infection. Experiments have been begun to see whether the fungus can be killed by immersing the " seed " in fungicides, as it no doubt can, and it has been shown that consistent attention to spraying with Bordeaux mixture (much more easily and safely carried out on plants grown for seed than in the growing of celery for market) will control the disease. It seems, therefore, probable that seed-growers have it within their power to provide their customers with clean seed.

It may be added that Celeriac, too, has fallen victim to the disease with increasing frequency during the past two years.

NOTES.

A MEETING of the Association was held in London on April 17th and 18th. Some of the papers read at the meeting appear in this issue and a complete list is attached. We regret that no complete account of the meeting has appeared in any paper but the accident which befell the Honorary Secretary three days before the meeting upset the arrangements including those made for reporting the papers and discussions. The chair was taken by the President, Professor Newstead, F.R.S., and after the election of members the following papers were read:—

Dr H. T. GÜSSOW. The Organism of Common Potato Scab. In the absence of the author this was read by Mr A. G. L. Rogers.

Mr A. S. HORNE. Potato Diseases.

Professor E. S. SALMON. Observations on the Perithecial Stage of the American Gooseberry Mildew (*Sphaerotheca mors-uvae*).

Professor PERCY GROOM. Brown Oak.

Mr A. G. L. ROGERS. The Phytopathological Conference.

Mr E. HARGREAVES. The Life-history and Habits of *Aleurodes vaporariorum.*

Professor R. S. MACDOUGALL. *Hylastes palliatus* and its rank as a Forest Enemy.

Mr E. E. GREEN read a recently published bulletin of the United States Department of Agriculture entitled "Economic Points in regard to the Migratory Habits of the House Fly."

Mr J. W. MUNRO. A Braconid Parasite of *Hylobius abietis.*

Mr F. J. CHITTENDEN. A Note on Celery Leaf-Spot Disease.

Mr H. WORMALD. A Bacterial Rot of Celery.

Mr R. A. WARDLE. Life-history Notes on two previously unrecorded Parasites of the Large Larch Sawfly.

Mr A. W. WESTROP. The Golf-green Maggot.

The PRESIDENT communicated a note by Mr A. D. WALKER on "The Migrations of the Coccinellidae."

The Scope of the Annals.

The *Annals of Applied Biology* has been founded to publish the scientific papers of the members of the Association and to represent as far as may be their interests. Its scope is as wide as the membership of the Association and we are not desirous of its falling into the narrow

rut of one limited subject. How wide its interests are to be, how extensive its scope, depends upon its contributors. We will endeavour to ensure the *Annals* reaching all who are interested in the subjects dealt with and we are securing a wide circulation outside our actual members.

We have already stated that purely systematic work in any group does not come within its scope ; nor does the enumeration of the flora or fauna of defined areas ; both are very amply provided for. We do however invite contributions in all branches of Applied Biology and efforts will be made to ensure that the *Annals* reach all centres of research in the subjects these papers deal with.

There is no desire to encroach on the spheres of influence of other journals and among our members are those who contribute to these journals ; we hope that papers will be read at the meetings which will perhaps be published in the *Journal of Agricultural Science* or elsewhere ; the Association does not claim the right to publish in the *Annals* all papers read at its meetings and we shall find a wide scope for the *Annals* without encroaching on the scope of other publications. We do hope that the range of subjects of our meetings and of our members may be so wide as to include workers in every branch of Economic Biology, whether they contribute to the *Annals* or not, and that the distinction between the scope of the meetings and membership and that of the *Annals* may be recognised.

The Association.

At the last meeting forty new members were elected ; there are, however, at least twice the total of our members in workers in Applied Biology who might reasonably be expected to become members. We hope that a large proportion of the potential members will become actual members : if our membership really embraces a large majority of workers and teachers in the Empire, the Association benefits, the individual member benefits and when the need comes, we may reasonably hope to be able to represent the interests of the whole body or of the individual in a satisfactory manner ; we do not propose to invite members to strike ; we are not a trade union ; we do not even propose to discuss the rewards given to scientists by the state, a subject that has considerably exercised a few prominent scientific men lately ; but a really representative Association is needed and can exert an influence attainable in no other way.

We hope also that the Association may be a focus for ideas and

knowledge; that members in distant parts of the Empire will send us notes and papers; that the originality developed by dealing with new problems may find expression in our *Annals*; and that we in England may be stimulated by the progressiveness of the Dominions and stirred by their newer and more thorough ways of tackling problems, born of the stress of circumstances of new lands. We are, in England, too prosperous, too peaceful, too settled; we are not at grips with problems that count; if one crop fails, another succeeds; we have not staked our all on a crop of apples nor does American Blight or Codlin moth really matter, bad though they are; nor if it does matter, can we apparently stir up any interest in getting anything done; so we in England take things easily, we have practically no legislation, every man may disseminate disease from his neglected garden and, in a great deal, we must look to the Colonies to give us a lead.

With this invitation we expect all who have interests common with our members here to join, and we look for support from all who are solving the big problems of applied biology and who can learn from the experience of others and with their own experience help others who have similar problems to work out.

Migration of Ladybirds.

The following note by Mr A. D. Walker, was read by Professor Newstead at the last meeting of the Association:

The following fact in the bionomics of the common "Ladybird" (*Coccinella*) may interest you.

Mrs Walker's bedroom has three windows, two facing south and one east. Since 8 a.m. to-day something like 100 Ladybirds have been taken on the east window *only*—none on the two south windows, except a few on the one next to the east end. The same thing happens every year—always the east window! It is not because of east winds for the winds here lately have been predominantly southerly and this morning there was a "moderate gale" from W.S.W.

There are roses trained both on south and east sides, so their presence will not account for Coccinella's preference for the latter.

The only way I can see to account for it is that there must be a spring migration from the continent. Our house, standing on the top of a fairly steep slope to the east, on which side there is a valley, would be a conspicuous obstacle to the insects flying across it. But it is curious that they should be so abundant this year when there has

been so little east wind and that with so much southerly wind, they should not strike the long south side of the house. It looks as if they could only cross the channel at the Strait of Dover which lies east from us; also that they can fly " on a wind "—*i.e.* with a side wind.

Another migration note. Last November countless flocks of Wood Pigeons flew over the great Kings Wood here. Some, perhaps all, stopped to have a feed of acorns but nearly all flew on to the west to become such a plague in Wilts and Dorset, that they have had armies of men with guns to shoot them. Here I can say with confidence that I have not seen a dozen since Christmas, though constantly in Kings Wood!

Surely this is a *blind* migratory impulse like that of the Lemmings!

Westminster Hall Roof.

The fine timber roof of Westminster Hall has suffered great damage from the attack of the larger timber-boring beetle, *Xestobium tesselatum.*

A committee has been meeting to advise the Office of Works and an investigation into the beetle has been commenced by Mr J. W. Munro at the Imperial College of Science and Technology. We refer to this since the preservation of this roof is really a matter of national interest and because members of the Association may be able to materially assist if they can help Mr Munro to get infested timber. Naturally the timber in the roof cannot be cut to provide material for experiment and a large supply of beetles and timber is an essential for testing the many possible lines of treatment that have been proposed. It is curious how little is known of this beetle and one very essential fact is not apparently definitely known, whether the beetles emerge from the wood or whether they can continue reproducing inside the large timbers, only emerging if they wish to. It might be easy to prevent the re-entry of beetles if they had to emerge, but, as it is, no treatment to the outside of the wood only can be adopted for fear it might keep them inside and intensify the damage. It is probable that a satisfactory treatment will be found.

Notes.

We shall be glad to receive notes on matters of current interest and on investigations in progress for publication in these pages; it is an accident that the notes in this issue are mainly of entomological interest; all members of the editorial Committee will be glad of short contributions which may be sent to them or to the General Editor direct. For the notes in this issue the General Editor alone is responsible except where stated.

H. M. L.

VOLUME I JANUARY, 1915 Nos. 3 and 4

SOME DIFFICULTIES IN THE IMPROVEMENT OF INDIAN SUGARCANES.

BY C. A. BARBER, D.Sc.

(*Imperial Department of Agriculture for India.*)

(Plates XIII—XVI and 3 Text-figures.)

THE need for improving the class of sugarcanes grown in India has long been recognised, and fitful efforts in this direction have been made during the last hundred years or more. These efforts have, almost uniformly, resulted in failure, chiefly owing to a lack of appreciation of the factors involved. The subject has, however, again forced itself on the attention of Government because of the steadily increasing imports into India of Java sugar. There is, in India, a much larger acreage under sugarcane than in any other country and it has been not unreasonably maintained that there must be something wrong if it cannot supply its own demand for sugar. The produce of the fields is, however, so low that it is quite insufficient to meet the demands of the growing population.

In approaching the problem anew, it has been considered advisable to make a closer study of the canes themselves and the conditions of soil and climate under which they grow than appears to have been done before, and certain intrinsic difficulties have been met with which may very easily account for former failures. Before considering these it will be well to indicate briefly the conditions referred to. For the sake of conciseness, it is convenient to divide the Indian sugarcane area into two parts, a northern and a southern, as indicated in the accompanying sketch-map. The southern portion, consisting of parts of Madras, Mysore and Bombay, is on the whole well suited for sugarcane growing. It is wholly within the tropics, the temperature is uniformly high throughout the year and, in many places, the soil is good. The rainfall is, however, of such a nature that irrigation is needed to supplement it. India is not blessed with the well-distributed rainfall of tropical islands

and, almost everywhere, there are long periods of drought, often extending for four or five months at a time. Where temperature and soil are suitable, moistness is found to be a limiting factor. In the north, the

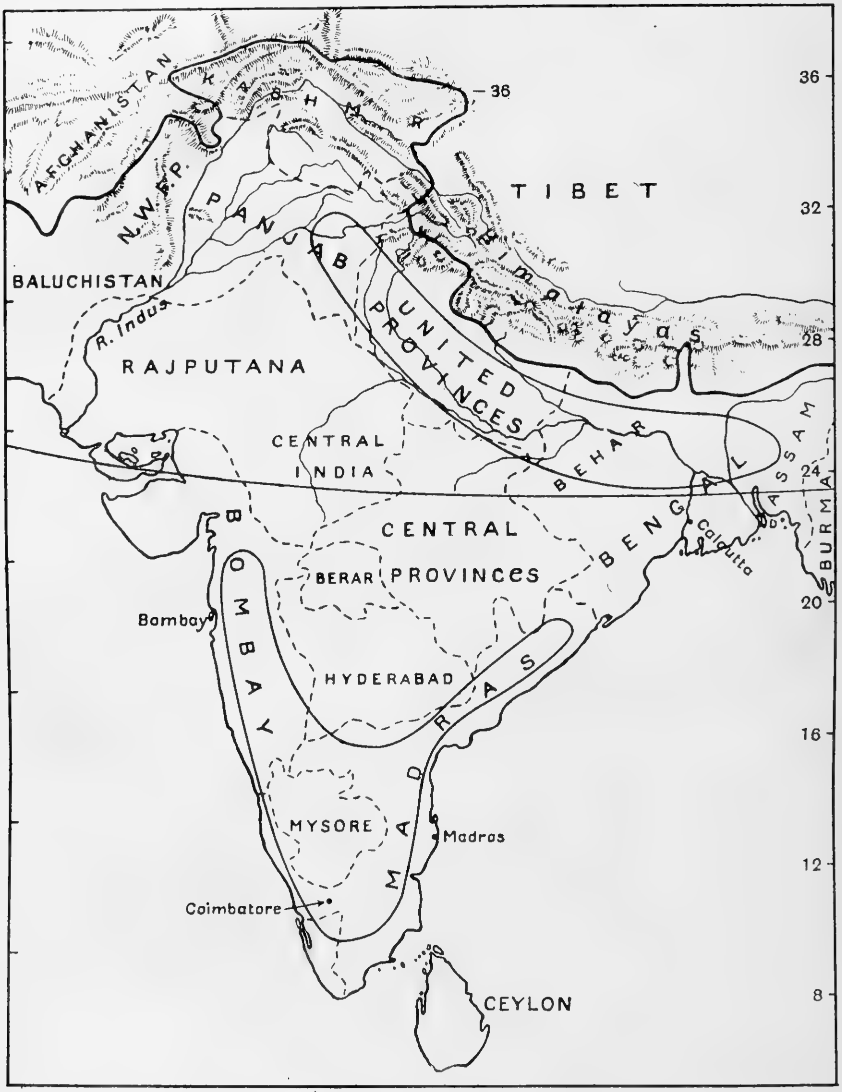

Fig. 1.

main sugarcane tract extends from Assam to the Panjab, along the foot of the Himalayas, a distance of over 1000 miles. On comparing the acreage of these northern and southern regions, it is found that the

cane is much more thickly planted in the former, so that vastly the greater part of the crop is grown in this northern region, constituting an aggregate of something like 4000 square miles. This is entirely outside the tropics. Moisture is adequate, by rain near the hills and a complete network of canals farther south where, however, paddy is no longer a serious rival. The soil is easily permeable, deep and rich, but the total amount of warmth and especially the length of the growing period are insufficient. The continuance of suitable high temperature is the limiting factor here.

This difference in climate between the northern or continental portion and the southern or peninsular has a marked influence on the character of canes grown in the two regions. While the field canes in Southern India are often comparable with those of tropical islands in thickness and vigour, those of North India are much thinner, more fibrous and much less productive of sugar in the crop. The canefields look very different in the two tracts, as may be gathered from the photographs, those in Bengal standing intermediate between the extremes of Madras and the Panjab. And, when the canes are carefully examined, they are generally so unlike in morphological characters and habit that it is worth while considering whether they have been derived from the same ancestral species of Saccharum. These differences in climate and character of the canes have a pronounced effect upon the whole course of cultivation in the field and, while the cultivation of sugarcane in the south is intensive and costly, the crop in the Gangetic plain has little attention paid to it.

Judging by the periodic returns issued by Government, the area under sugarcane remains more or less stationary, but, on the other hand, the population is rapidly increasing. It is still doubtful whether the diminution in poppy-growing will bring much more land under sugarcane, and although there are indications of extension in some localities, there is no immediate prospect of any great increase in the area under this crop. Improvement in production must therefore take the line of increasing the yield per acre. With this object in view, a small department has recently been opened by the Indian Government for the general study of the sugarcanes of the country. There are, of course, various ways in which the problem may be approached. Leaving aside the whole question of improvement in agricultural practice, which is now receiving a good deal of attention, the canes are seen to be obviously inferior in character in North India, and it is natural to consider whether success may not be obtained most rapidly and

economically by replacing them with better kinds. There are four ways in which this may be attempted:—

(1) *The introduction of exotic canes which have proved of value elsewhere.* This method has been the main line followed for many years all over India, from Madras to Peshawar. Thick, tropical canes, the relics of successive importations, are everywhere met with. But it is generally found that these thick canes have not time to mature in the north during the short, hot, moist period. They sometimes grow surprisingly well and are full of juice, but the ripening process by which the glucose is changed to crystallisable sucrose is arrested and, although extensively used as fruit and eaten raw, these thick exotic canes are generally useless for the manufacture of sugar. It is possible that certain early maturing varieties may still be met with, or that changes in treatment may lead to improvement along this line, and this is not being lost sight of, but we have the advantage of actual demonstration of their behaviour all over the country and the prospect of success is not encouraging.

(2) *The transfer of canes from one part of India to another.* This method of improvement is well known to the cultivator. He is not only accustomed to the trial of new varieties valued elsewhere, but is acquainted with the advantage of occasional change of seed in the same variety. Exchanges of varieties are being actively carried on by the Agricultural departments of the various Provinces and occasional advantage accrues from this. Collections of different varieties of sugarcane growing together are a constant feature on local farms. The fine new canes introduced into Madras through the Samalkota farm are now to be met with in every part of India, even extending to the North-West Frontier Province. But success along this line is limited and, in the main, the introduced kinds cannot hold their own against the best local kinds, the latter themselves being the outcome of centuries of selection by the cultivators.

(3) *The improvement of local canes by selection and the observation of sports.* This method has perhaps hardly received the attention during recent years that it undoubtedly deserves, but there are special difficulties in the way with a crop that can only be finally judged after it has passed through the mill and been chemically analysed. The sugarcane has, from time immemorial, been propagated by cuttings, and it is difficult to determine whether chance variations in growth are or are not due to better local treatment or feeding.

(4) *The production of seedlings.* This has been tried many times

in India, but in the past always unsuccessfully. The experiments have not always been conducted very carefully, and on the founding of the new department it was decided to examine the matter afresh and try to determine the cause of failure in the face of the successful results obtained in Java, the West Indies and elsewhere. The solution of the problem turned out to be remarkably simple. Almost all the experiments were made in North India and it transpires that the stamens do not mature and pollen is not formed in the cane flowers there. A cursory glance showed that this was not the case in South India, and in the Government farm opened at Coimbatore in the Madras Presidency some 40,000 seedlings have been raised during the past two years.

Problem 1. During the short time that the cane-breeding station has been in existence, a very important step in advance has been taken and the first problem, that of obtaining seedlings, has been solved. But in considering the ultimate aim of the station more carefully, a number of difficulties have cropped up and it is the intention in the present paper to detail some of these further problems, in the hope that help may be available from the great body of readers interested in plant-breeding.

Problem 2. Most, if not all, of the difficulties in procuring suitable cane seedlings have arisen from the fact that the flowering is irregular—in fact, comparatively rare. If a cane flowers and we obtain seedlings from it, we cannot count on these seedlings flowering. We have no means at present of inducing the canes we are most interested in to flower. Control of the flowering is the second difficulty we have encountered.

Arrowing of the cane, as the production of the inflorescence is called, is comparatively rare in North India, but occasionally it occurs over large areas. It is viewed with alarm in certain regions, and there appears to be some reason for connecting it with the weather and especially with a failure of the normal rains. Flowering of the sugar-cane appears to be commoner in years of drought, but details on this point are not yet available. In Mysore and Coimbatore, typically dry tracts, flowering is common, and on the other Madras farms where sugar-cane is grown, in Malabar, Godavari and South Arcot, the amount of flowering seems to vary inversely with the moistness of the climate. On the other hand, it is a common belief among Coimbatore cultivators that arrowing is most frequent in water-logged conditions of the roots. Experiments are now being conducted on the farm with different soils and different amounts of moisture to see if any effect is produced,

for it is felt that, until some control of flowering is obtained, working along Mendelian lines is more or less out of the question. If the supposition of the Coimbatore ryots is correct, it would seem to indicate that flowering ensues whenever the flow of sap is interfered with, whether by the paucity of water or the unhealthiness of the root system.

Problem 3. Another matter which has attracted our attention is that there appears to be a very close relation between richness and purity of juice and vigour of growth. The first requisite in a seedling cane is a high percentage of sucrose and purity of juice, but the total quantity of sugar is what is aimed at in the field, and this will obviously depend upon vigour of growth and the number and size of millable canes in the crop. The first year's seedlings when analysed and weighed showed a markedly converse relation between purity and vigour. The smallest and most meagre plants had the richest juice and those seedlings which were distinguished by the abnormal vigour of seedlings were very poor indeed in sucrose content. Richness and purity, if dependent on lack of vigour, may to all intents and purposes be regarded as a diseased condition and, if so, must be very carefully distinguished from purity and richness which are inherent and varietal. Among my colleagues, Mr Parnell has drawn my attention to a similar relation in indigo seedlings between meagre leaf production and richness in indigotin, and Mr Anstead states that, in analyses made by him of individual rubber trees in South Indian plantations, the latex richest in rubber was obtained from poorly grown or stunted trees.

Problem 4. One important line of work in the cane-breeding station is the selection of suitable parents and inducing them to flower together. But, even if we are successful in this, we are confronted with another serious difficulty. How shall we determine if seedlings obtained are really crosses? We can approach this problem either directly or indirectly. In the first place we may actually cross the two varieties with scientific precautions against self-fertilisation. This has been successfully carried out in Barbados for several years. In Coimbatore there are special difficulties in the way. The bulk of the canes arrow during the heart of the north-east monsoon, a period of violent winds and torrential rains. As the long stalk of the inflorescence (arrow) is very easily damaged and the slightest bend appears to cause it to wither, we have to erect over each arrow a gallows-like support, with a hanging iron cage covered with muslin—much after the plan adopted in Java. The difficulties in crossing such inflorescences can be readily imagined. There are an enormous number of flowers on each arrow and the male

and female organs mature at practically the same time. For certain crossing it will be necessary to emasculate all the flowers of one parent arrow. Even if we succeed in cutting off the majority of the flowers without injuring the rest, each experiment would mean the erection of a lofty staging with practically a glasshouse at the top in which an assistant could use a dissecting microscope. The state of the weather would usually render futile any less cumbrous arrangement. This is at present out of the question. Certain, direct crossing does not at present appear to be feasible at Coimbatore and, added to this, the outlook for such work is discouraging because the results obtained at Barbados appear to have been unsatisfactory, one after another of the carefully nurtured crosses having been abandoned on being tested in the field.

There are two ways which suggest themselves of approaching the problem of obtaining known crosses indirectly. It has been noted that the different cultivated varieties of sugarcane vary a great deal in the development of their essential organs. Some have never been observed to flower: others have flowers which do not emerge from the enveloping sheaths: yet others have partial or total sterility in male (or female?) organs, while a number produce healthy arrows with good pollen and fertile ovules. The commonest case at Coimbatore is that only a certain percentage of stamens open. If we could obtain a variety in which no pollen is formed at all or no stamens open (and there seems to be a close relation between the two, stamens which do not open not containing fully formed pollen and the converse), crossing that variety with one producing good pollen would be easy. One or two such cases have already been observed and crosses obtained, but these happen to be of little value from the economic point of view. The best local cane at Coimbatore, the 'Vellai,' arrows freely every year but produces comparatively little good pollen. Advantage has been taken of this during the past year to pollinate this variety with about a dozen others, in the hope of obtaining crosses between them. The withered flowers of each arrow are kept and carefully analysed as to the percentage of open anthers, and the probability of obtaining crosses or selfed seedlings is calculated therefrom. But, unfortunately, some open anthers are always noted (often about 2 %) in Vellai, and we shall have to depend on further study of the seedlings before we can definitely say whether we have been successful.

A second way of approaching the problem indirectly is opened for us by the fact, now observed for two years, that certain varieties produce

many seedlings, when selfed, which, however, die off at a very early stage. In one case 13 survived out of 4000 in the first year, and a hundred or two out of 10,000 in the second. This would appear to be a varietal character, and two other kinds appear to share this peculiarity. It is, therefore, proposed to pollinate these three, if possible, from other good kinds during the next season on the chance of obtaining a more vigorous lot of seedlings. If we succeed in raising thereby a large number of vigorous seedlings, it may be safely assumed that the bulk of them will be crosses.

Problem 5. It has been suggested that it may be possible to decide the parentage of seedlings by observing their subsequent habit and growth, but we shall require for this purpose a very complete knowledge of the morphological differences of the parents. The problem of classifying the canes thus acquires additional importance. Considerable progress has been made in this direction during the past year and a half. A remarkable number of minute distinguishing characters have been recorded in examining the different canes collected, although this work is still far from complete. A few of these characters may be mentioned here and those interested in the subject are referred to a paper on "The Panjab Canes" about to be published as a Memoir of the Indian Agricultural Department. In this paper a summary of the chief characters studied up to date is given, in order to explain the descriptions of the canes figured.

The habit of the cane as it strikes the eye appears to be extremely important and characteristic. Its erectness, tillering power, shooting of buds, rooting at aerial nodes, leaf angle and leaf endings, as well as liability to be attacked by certain fungi, form useful determining characters. The joint (made up of a node and the internode above it) varies in thickness, length, shape, number, growth curve (the relative length and thickness in different parts), ovalness, hardness of rind, quantity of fibre, juiciness, richness and other properties of the juice, colour, waxy bloom and relative development of leaf scar, circlet of hairs, root zone, growth ring, bloom band, etc., in different varieties. The bud presents important details as to shape, size, mode of bursting, flanges (lateral expansions of basal scales), vestiture in bristles, basal patches of hairs and minute black hairs. The lamina, leaf-sheath and ligule all show similar acts of diagnostic characters, in which various types of hairs play an important part, the leaf-sheath especially presenting a surprising number of differences. As a result of this minute morphological examination of the canes, there appears to be some

prospect of arranging the Indian canes into a series of alliances, although it is not always possible to determine whether similar canes from

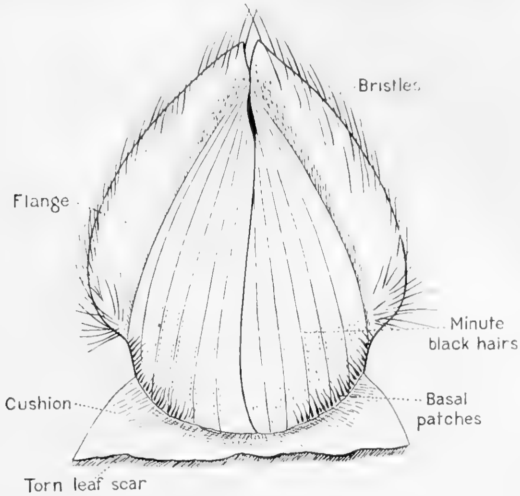

Fig. 8.

different localities are permanently separable or merely local varieties induced by their special surroundings. A natural system of classification is being attempted in which the members of the different groups

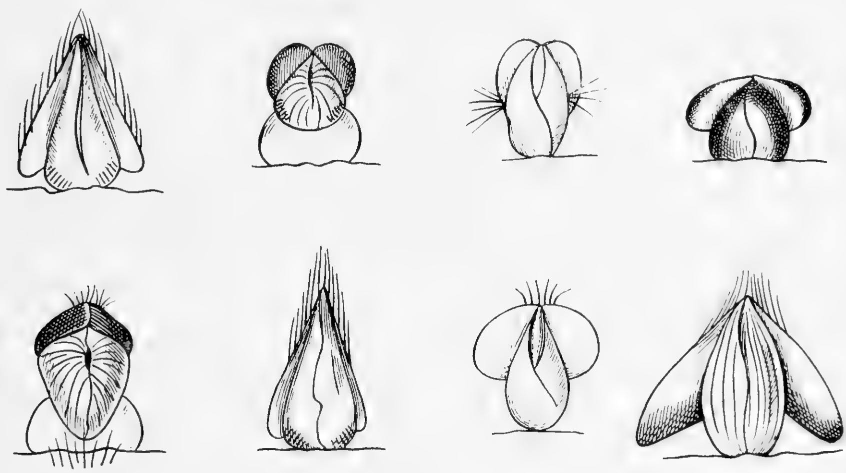

Fig. 9.

resemble one another in as many as possible of the characters referred to above. In such a system agricultural, botanical and chemical characters will all have a place.

Problem 6. The question now naturally arises, are these characters

constant in different localities and under diverse conditions? What stability is to be expected in such minute vegetative separating marks and what are the limits of variability, especially in quantitative characters? There is no doubt that the sugarcane responds very readily to change of habitat. This fact will increase the scope of the detailed study described in the last section, in that the same varieties must be studied for several successive seasons both in North India and at Coimbatore. We already know of characters which are unstable in certain varieties under changed conditions, although they appear to vary less in others. The ivory markings in the joint are usually a good character, but in some kinds of cane they are readily affected by changes in climate (moisture?). The colour of the cane has been observed to change in some varieties in transfer. Canes which appear to be immune to fungus attacks in one district are at once attacked and destroyed by the same species of fungus in another. There are a number of other characters which have been noted as varying in this way, and it is possible that, while firmly fixed in certain kinds of cane, they are variable in others. These facts will naturally increase our difficulties when we attempt to trace the characters of any parent in a seedling by observing its morphological characters. But, in consideration of the facts noted in the next paragraph, it will be seen that these difficulties are greatly increased.

Problem 7. Of what value are the characters noted above in separating seedling canes? Are any of the minute differences observed in varieties propagated vegetatively handed down unaltered in seedlings derived from them? At present there is not sufficient material available to answer these questions. But one of the most obvious features in any batch of seedling canes from a common parentage is the extraordinary amount of variation among them. And this is especially noticeable in those characters of habit which appear to be so stable and valuable in varieties in the field. The seedlings appear to differ in every direction—habit, joint, colour, leaf, juice, etc. We have already collected a certain amount of material for the detailed study of this question. Last year we obtained 70–80 seedlings from Strakarchynia (a thin Behar cane) fertilised by *Saccharum spontaneum*; 13 from Chin (a thin U.P. cane) also fertilised by *Saccharum spontaneum*, and 71 selfed seedlings of Saretha (a thicker cane of the U.P.). As far as time has permitted, a detailed study has been made of these seedlings and the descriptions of them recorded, and it is hoped that, when these descriptions are analysed, some useful facts may be obtained. One difficulty is encountered, however, in our inability to apply the

Fig. 2. A canefield in Madras.

Fig. 3. A canefield in Behar.

Fig. 4. A canefield in the Panjab.

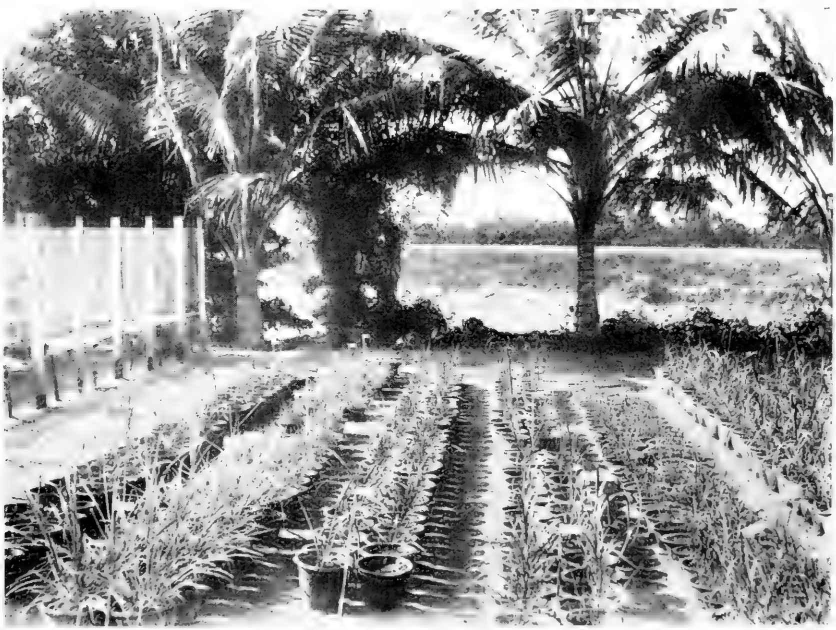

Fig. 5. Cane seedlings at Coimbatore.

Fig. 6. Cane arrows, left Vellai, right Ashy Mauritius, middle *Saccharum narenga*.

Fig. 7. Arrows protected from casual pollination.

Fig. 10. Saretha cane in the field.

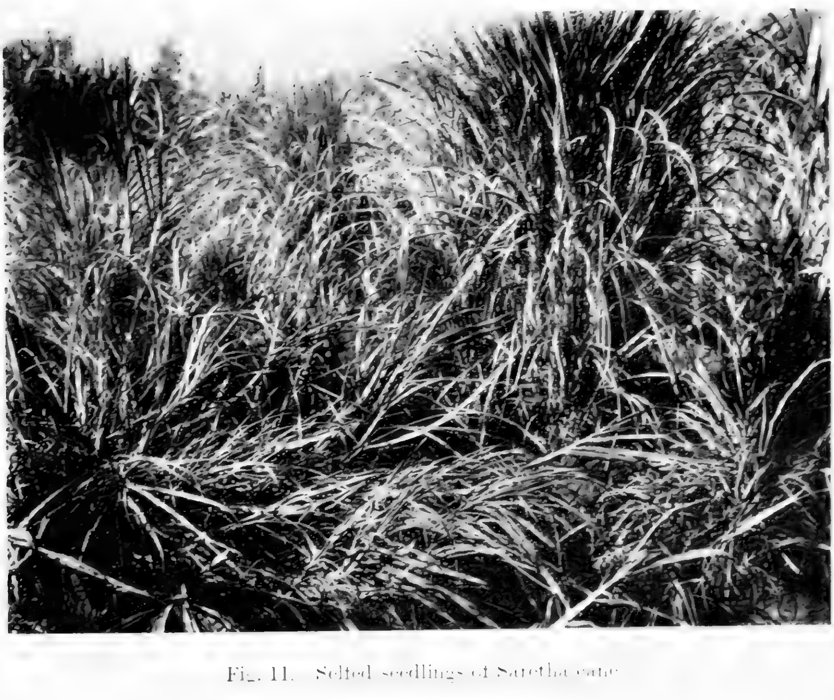

Fig. 11. Selfed seedlings of Saretha cane.

stereotyped description of cultivated canes (*Saccharum officinarum*) to the wild *Saccharum spontaneum*, for this species is regularly propagated by seed all over India, and the seedlings appear to vary so much among themselves in certain characters that individuals may be placed in almost all the groups already marked out among the cultivated forms. This, however, is a fact not without its significance in our efforts to trace these cultivated forms from *Saccharum spontaneum* itself.

The attempt to determine the parentage of seedlings by their morphological characters of their vegetative parts is thus beset with difficulties, and these are not decreased by the possibility of many characters being intermediate or recessive in the offspring.

Taking these uncertainties into consideration—and there are, naturally, many chemical and agricultural ones not yet fully grasped—the main line of work in the cane-breeding station for the present lies in the direction of selecting suitable parents, preserving the healthy offspring of the best of these, analysing the juice after the first year's growth and observing the relative vigour of growth and choosing the best for further observation—a narrowing circle in which ultimately a few of the best all-round will remain to be sent to the chain of agricultural stations in the north for a renewed series of tests there before dissemination among the cultivators. In all cases it will be our aim to cross good North Indian canes with good South Indian or Exotics, and in the case of the former the importance is recognised of choosing one parent which is largely grown and valued in the particular part of India to which it is intended to send the resulting seedling for trial.

EXPLANATION OF FIGURES.

Fig. 1. Map of India indicating roughly the northern and southern tracts over which sugarcane is grown. The acreage under cane is ten times as great in the northern region as in the southern.

Fig. 2. A modern canefield in Madras.

Fig. 3. A good canefield in Behar.

Fig. 4. A good canefield in the Panjab.

Fig. 5. Cane seedlings at the Cane-breeding Station at Coimbatore.

Fig. 6. Cane arrows, in left of Vellai, in right of Ashy Mauritius. In the middle, the arrow of *Saccharum narenga*.

Fig. 7. Arrows protected from casual pollination (at a village ten miles from the cane-breeding station).

Fig. 8. A typical sugarcane bud.

Fig. 9. Various forms of sugarcane buds.

Fig. 10. Saretha cane in the field—a moderately thick North Indian variety—with very characteristic, erect and ascending shoots.

Fig. 11. Selfed seedlings of Saretha cane. These vary from strict, erect to absolutely prostrate seedlings. The latter are seen in the foreground (left) and the prostrate habit is fixed in all descendants produced vegetatively from them.

THE PEA THRIPS (*KAKOTHRIPS ROBUSTUS*).

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(With 12 Text-figures.)

CONTENTS.

History.

Although no doubt damage has been caused to peas and beans for many years by thrips, apparently the first record of such an occurrence is found in 1871 when A. Müller[1] describes shortly, without however mentioning any locality, an attack on peas, which was certainly due to the species here discussed.

In 1880 Westwood gives a much fuller account of an attack at Oxford, with figures of the damaged flowers and characteristically curled pods. He gives the name *Thrips pisivora* to the black-tailed yellow larvae, which were in numbers on the damaged plants, under the impression that they were the adult females, and only just mentions

[1] All references will be found under author and year in the Bibliography at the end.

the real adult as a black winged form which he supposes to be the male! As his name was given to the larval stage it has to be given up in favour of Uzel's name of fifteen years later.

In 1890 Kirchner shortly described damage to peas in Germany as due to *Thrips cerealium*. This name, however, was at that time used to designate any Thysanoptera, and, as in 1897, he figures the orange black-tailed larva, there is no doubt that he was dealing with the present species.

In 1895 Uzel described *Physopus robusta* occurring in various flowers in Bohemia.

In 1898 the Board of Agriculture of England published a leaflet (revised in 1905) entitled *Pea and Bean Thrips, Thrips pisivora*, in which an account is given of damage to field and garden peas and beans and also to scarlet runner beans (*Phaseolus vulgaris*). A copy of two of Westwood's figures is given and an account of the life-history which is either due to mistaken observations or else should apply to some other species. It is stated that the eggs are loose in the flowers, that the nymph or pupal stages are found in the flowers and that the insect hibernates as an adult. This latter belief, which has become very widely spread, has caused many entomologists to recommend the burning of the pea sticks during the winter, a proceeding which, as will be seen, is quite useless.

In 1899 Trybom gave a very full account of a bad attack by the larvae of *Physopus robusta* on peas near Stockholm and in Ostergotland in Sweden. The attack was worst at the end of July and became so bad that the whole plot had to be dug up and burnt. The larvae were found in the bunches of unopened leaves at the growing points and caused these to shrivel up; they attacked the pods, causing them to discolour and curl. Eggs were found embedded in the tissue of the plant at the bases of the young leaves and stipules. No pupae were seen nor were any obtained by keeping the larva in captivity.

In 1900 Theobald described an attack of Thrips in scarlet runners (*Phaseolus vulgaris*) at Crawley, Sussex. This must have been due to some other species, as he does not mention the dark tail to the larva and found the pupal stages in the flowers and also that the adults hibernated. From the figures it would appear to be a species of *Frankliniella* and may be *F. intonsa* which I have found commonly in scarlet runners. In 1906 and 1907 the same author gives accounts of attacks on peas which were undoubtedly due to *K. robustus*.

In 1908 Warburton published an account of this pest and described

the eggs which he found embedded in the tissue of the stamen sheath. He also believed that the insect hibernated in the adult stage. He suggests as a remedy 'topping' the plants as is done in beans for 'black-fly,' as he found that the topmost shoots were most badly attacked.

In 1913 I myself gave a preliminary account of the life-history, showing that it is single brooded and passes the winter as a full fed larva in the soil beneath the infested plants.

In 1914 Vuillet (ii) described a Chalcid *Thripoctenus brui* n. sp. which he found among larvae and adults of the pea thrips in France and which he believes to be parasitic on it.

Recently [Williams, 1914] I have separated the species *robustus* from the genus *Frankliniella* and have erected for it a new genus *Kakothrips* on characters which will be given later. There are several shorter or less important references which will be discussed as occasion arises.

Species and Synonomy.

Although several different species of thrips may at times be found in peas and beans, there is one in particular which seems always to be present in large numbers when any severe damage is recorded. This is at present known to systematists as *Kakothrips robusta*. It belongs to the family *Thripidae* of the sub-order *Terebrantia* of the Thysanoptera.

To the unaided eye it appears as a minute black insect about a twelfth of an inch (2 mm.) long, linear, more or less pointed at each end, with short slender antennae. There is a lighter band across the thorax due to the bases of the wings being pale coloured. The lighter rings on the abdomen described by several authors are merely the soft and lighter coloured connecting membrane between the abdominal segments which shows when the body is distended, usually by killing in alcohol.

As the literature on the Thysanoptera is very scattered and often difficult to obtain, the following notes on the characters of the family and sub-order are given:—the sub-order *Terebrantia* is chiefly characterised, and may be easily recognised, by having the terminal segments of the abdomen more or less constricted to a point (in the *Tubulifera* the tenth segment is tubular), by having a saw-like ovipositor in the female and two longitudinal veins more or less distinct in the front wing. The family *Thripidae* has the antennae six to eight segmented and the ovipositor of the female curved downwards.

Genus Kakothrips *Williams* 1914.

Characterised as follows:—antennae eight segmented, maxillary palps three segmented. Labial palps two segmented. *Ocellar spines between the posterior ocelli.* Fore vein of the front wing set regularly throughout its whole length with spines. *Short lateral processes on each side of the eighth abdominal segment in the male, curving backwards and upwards; rudimentary but distinguishable in the female.* Larva with 9th and 10th abdominal segments dark coloured.

Type *K. robustus* (Uzel 1895).

The characters in italics distinguish it from the genus *Frankliniella*[1] Karny, to which it is closely allied.

Kakothrips robustus.

—— Müller 1871.

Thrips pisivora Westwood 1880. Board of Agriculture leaflet 1898 and 1905. Theobald 1900, 1906, 1907. Collinge 1906. Warburton 1908.

Thrips cerealium Kirchner 1890, 1898.

Physopus robusta Uzel 1895. Trybom 1899. Buffa 1907.

Thrips physapus von Schilling 1898.

Euthrips robusta Bagnall 1908.

Frankliniella robusta Williams 1913. Vuillet 1914.

Kakothrips robustus Williams 1914.

Female (Fig. 1).

Measurements. Head, length 0·170 mm., width 0·190 mm.; prothorax, length 0·200 mm., width 0·250 mm.; pterothorax, length 0·380 mm., width 0·340 mm.; abdomen, length (not extended) about 1·10 mm., width 0·40 mm.; wing, length (from tip of basal lobe) 1·15 mm., width (about half-way along) 0·09 mm.

Antennae	1	2	3	4	5	6	7	8
length (μ)	24	46	74	70	54	68	12	18
width (μ)	40	30	26	26	22	22	10	8

Total body length of living specimen 1·85 mm. (usually 2 mm. or over in specimens killed in alcohol), antennae 0·4 mm.

Colour. Whole body, legs and antennae dark brown, except for the third and base of fourth antennal segments, the tarsi and fore tibiae, which are paler. Fore wings heavily tinged with brown, lighter at the base, hind wings almost transparent.

Head broader than long, cheeks almost parallel. *Eyes* dark not protruding. *Ocelli* present, forming an equilateral triangle; crescents distinct. Two small setae in front of the anterior ocellus and one on each side near the margin of the eye.

[1] Uzel's *Physopus* (= *Euthrips* Hinds) was split up by Karny (1907) into five genera, one of which was *Physapus*. This name being already occupied it was changed (Karny 1910) to *Frankliniella*. The type of this latter genus is *F. intonsa* Trybom (= *F. vulgatissimus* Uzel).

The two long ocellar spines are between the posterior ocelli. A long spine behind each eye and two pairs of short ones in a row between these. A few short forwardly directed spines on the cheeks. Faint striations near the hind margin of the head. *Mouth cone* short and rounded, reaching about three-fifths across the prosternum. *Maxillary palps* three segmented, the second segment shorter and the third longer than the first. *Labial palps* two segmented, the basal joint very short. Antennae more than twice as long as the head; the 1st segment short and broad, barrel-shaped; the 2nd broad and truncate at apex; 3rd the longest with short pedicel and dorsal forked trichome; 4th spindle-shaped slightly broader at the apex than at the base, with ventral forked trichome; 5th narrowing slightly in the distal third

Fig. 1. *Kakothrips robustus*. Female.

and then truncate; 6th spindle-shaped; 7th shorter and broader than 8th. Colour: 1 and 2 dark, 3 and basal half of 4 light yellowish-brown, apical half of 4 and 5, 6, 7 and 8 dark.

Prothorax wider than long and longer and wider than the head. Two long spines at each hind angle and one at each front angle, also two not quite so long on the front margin, and four or five pairs of short ones on the hind margin, the inner pair being longer and stouter than the others. A few minute setae scattered over the pronotum. Very faint striations near the hind margin. *Pterothorax* large, front angles rounded. *Legs* normal, all tarsi yellow, fore tibiae paler than femora. The small projection on the front tarsus noted by Uzel (1895, Fig. 55) is not always distinct. Two rows of stout spines on the hind tibiae. *Wings* reaching to the ninth abdominal segment. Fore wings clouded with brown except at the base; 25–30

spines on the costa, 17–20 on the fore vein, and 13–16 on the hind vein. Hind wings clear, the single vein indistinct but distinguishable to near the tip of the wing.

Abdomen. The ventral pleurites pectinate posteriorly. A very short projection on each side of the eighth abdominal segment (corresponding in position to the much larger ones in the male). A row of short pointed tooth-like projections on the hind margin of the eighth tergite. The tenth segment longer than the ninth and split dorsally for about three-quarters of its length from behind.

Male (Fig. 2).

About one-sixth smaller than the female. All the antennal segments, especially the first two, much paler than in the female. On each side of the eighth segment is a short process curving backwards and upwards and ending in a blunt point. The

Fig. 2. *Kakothrips robustus.* Male. *a*, outlines of two forms of clear areas on the third to seventh abdominal sternites.

transparent areas on the 3rd–7th sternites are elongate, but vary slightly in outline as shown in Fig. 2 *a*. Otherwise similar to the female.

Uzel's type specimen is in the Bohemian Landes Museums, Prep. No. 13, but as there is no doubt as to the identity of the species the above description has been made from British specimens.

Separation from Frankliniella intonsa.

The only other closely allied species which occurs in peas and beans and with which the pea thrips might be confused is *Frankliniella intonsa.* This can, however, be distinguished by the absence of the

lateral processes on the abdomen in either sex and by the following other characters:

K. robustus.	*F. intonsa.*
Size larger 1·85 mm.	Size smaller 1·3 mm.
Colour very dark in both sexes.	Colour slightly paler in female, male light.
3rd and base of 4th antennal segments light.	3rd, 4th and base of 5th light.
Long ocellar spines between the posterior ocelli.	Long ocellar spines between the posterior and anterior ocelli.
3rd and 10th abdominal segments equal in length.	10th abdominal segment longer than 9th.

Habits of adult.

Time of appearance. In the south of England the adult insects usually appear from the middle to the end of May. The earliest date observed in 1912 was the 28th May, in 1913 23rd May, and in 1914 the 16th May. Several correspondents speak of damage due to 'Thrip' earlier than this but have never been able to supply me with specimens. In the north of England it is later; in Sweden (Trybom) adults were first noticed on the 1st July, while, on the other hand, Gaumont and Vuillet (1914) found it in France at the end of March.

The first specimens are found in the terminal clusters of unopened leaves and in the just opening flowers. Specimens collected at this time contain a large number, sometimes even a majority of males (*e.g.* 16. v. '14 Merton, 9 ♂♂ 4 ♀♀ in flowers of *Vicia faber*). Later in the year the proportion of males becomes smaller and they soon disappear. With the exception of one dead specimen found at the beginning of August (Kendal, Westmorland) I have found no males after the end of June and, indeed, very few after the middle of this month. The females, on the other hand, gradually increase in numbers to about the middle of June (later in the north) and remain more or less common till towards the end of July, and may be found on into August together with full fed larvae on late sown peas. Bagnall (1908) found them in Scabious flowers in Durham as late as "August and September."

The males are more active than the females and escape more rapidly from the flowers when disturbed. The females are often very sluggish and do not leave the shelter of the flower unless this is pulled to pieces.

A female was kept in captivity for over a month and then only died by accident. It is probable that they live much longer than this.

Pairing takes place in the manner usually found in this group. It has been described and figured by Buffa (1907, p. 48) for *Aeolothrips fasciata*. The male climbs on the back of the female with its front legs on the thorax of the latter and the end of its abdomen curled underneath that of the female.

Parthenogenesis. Although the males are quite common early in the year and pairing has been observed to take place, yet the eggs are quite capable of developing parthenogenetically; eggs laid by a female bred in captivity and known not to have paired developed in the normal manner. In many other species of Thysanoptera parthenogenesis is quite normal, in some the male being still unknown.

The adults do not readily take to flight and when they are forced to do so it is usually only for a very short distance. I have no evidence as to whether they are capable of long sustained flight and migration, such as is the case with the corn thrips (*Limothrips cerealium*).

The food of the adults consists, like that of the larvae, of the juices of the plant, which are taken in by a piercing and rasping action of the three stylets in the mouth. They usually confine themselves to the soft tissue inside the flower and also suck the pollen.

The actual act of *oviposition* has not been observed in this species, but in a closely allied species *Taeniothrips primulae*, which lays more openly in the leaves and flower-stalks of the primrose (*Primula vulgaris*), it seems likely that the egg flows gradually into the slit made by the ovipositor similar to the method recently described for a sawfly by Chapman (*Trans. Ent. Soc. Lond.*, 1914, p. 173). Although the egg is very large compared with the size of the insect, it could not be seen to pass in bulk into the prepared slit.

The Egg (Figs. 3, 4 and 5).

The egg is, as is typical for this family, soft, opaque white and more or less bean-shaped but varies slightly in contour, sometimes the head end being more projecting (Fig. 3). It is 0·35 mm. long × 0·25 mm. broad and is large compared with the size of the parent. It is laid embedded in the tissue of the plant, in a slit made by the ovipositor. The slit is at an angle to the surface and the posterior end of the egg is at the bottom, while the anterior (head) end is at the opening quite visible from the surface and often projecting slightly above it.

By far the greater number of eggs are laid in the outer surface of the sheath round the stigma or young pod formed, in leguminous

plants, by the united stamens. This 'stamen-sheath' is very soft and succulent and forms a very suitable environment for the soft egg and also food for the freshly emerged larva. As many as 70 eggs have been counted in a single stamen sheath of *Vicia faber.*

Eggs are also laid, in smaller numbers, in the young developing pod, chiefly at the apex, where it projects beyond the stamen-sheath, or at the base where there is an entrance to the interior between the two edges of the sheath; in the petals (keel, aleae, and rarely standard); in the calyx; and also in the young shoots and leaves in the terminal clusters. This latter situation seems to be rare in this country; I have only

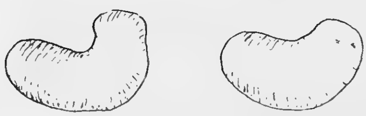


Fig. 3. Eggs. Much enlarged.

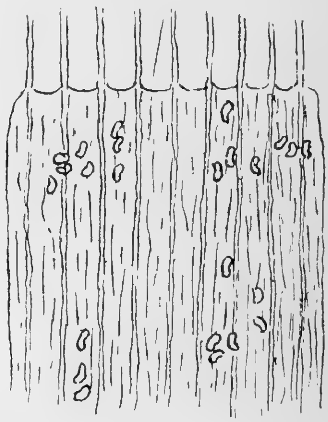


Fig. 4. Eggs in stamen-sheath of Pea. Diagram.

found a very few eggs there, but Trybom (1899) mentions it as the chief place of oviposition in the attack he observed in Sweden.

About five to seven days after being laid two red eye-spots appear at the head end of the egg. These, as pointed out by Warburton (1908), make the egg quite conspicuous in the pale yellowish-green of the stamen-sheath. Two or three days later (total 7–10 days) the young larva emerges.

Larval Stages.

First stage larva (Fig. 6).

The young larva as it emerges from the egg has the antennae bent down below the head, but either before or just after freeing itself from the shell they take up the normal position. The larva is now about

0·5 mm. long, semi-transparent white; the abdomen being unexpanded the legs appear very large in comparison, the hind legs reaching back almost to the tip of the abdomen. The abdomen extends rapidly on

Fig. 5. Micro-photograph of stamen-sheath of broad bean with eggs of pea thrips. × 6.

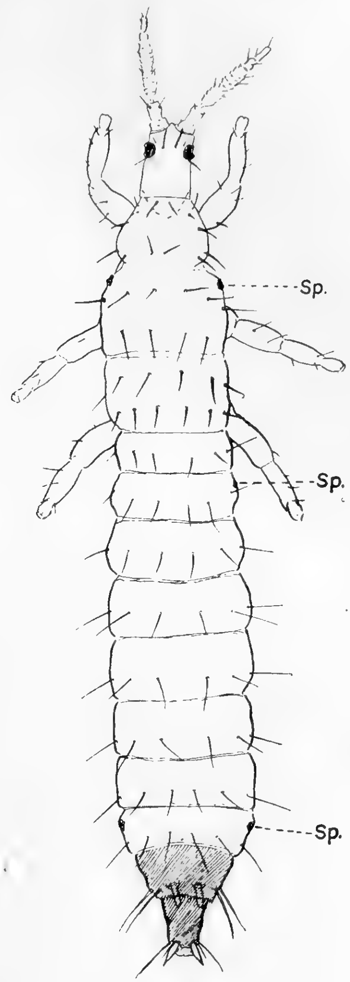


Fig. 6. First stage larva. *Sp.* = spiracle.

feeding and the last two abdominal segments begin to darken. After two or three days the body colour changes gradually to orange but does not become so bright as in the next stage.

Description of first stage larva.

Measurements. Total length varies from 0·5 mm. when just hatched to 1·1 mm. when about to cast its skin.

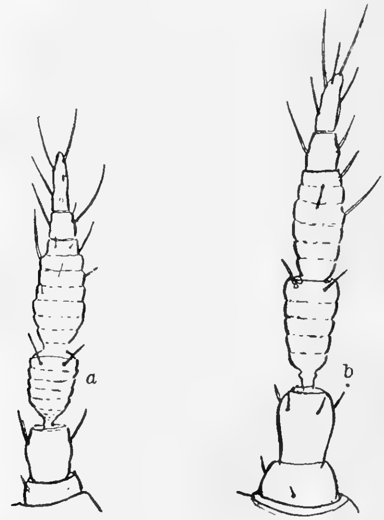


Fig. 7. Antennae. *a* of first stage larva. *b* of second stage larva.

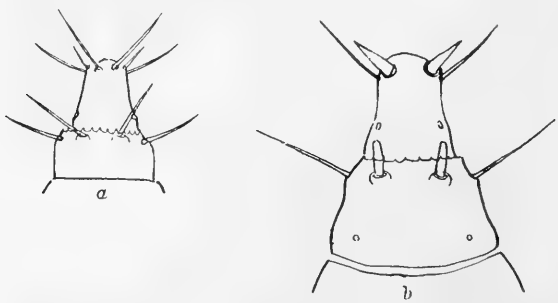


Fig. 8. Ninth and tenth abdominal segments. *a* of first stage larva. *b* of second stage larva.

Width of head across eyes 0·080 mm.
Length of ninth abdominal segment 0·040 mm.
Length of tenth abdominal segment 0·060 mm.

Antennae	1	2	3	4	5	6
length (μ)	18	28	40	54	12	30
width (μ)	31	25	25	27	12	9

Total length of antennae 0·18–0·2 mm.

Antennae (Fig. 7 *a*) six segmented, the third and fourth segments divided by narrow non-transparent rings into sub-segments. There are five or six of these

rings on the third segment and six on the fourth. The fourth segment is slightly wider than the third.

The darkly coloured ninth abdominal tergite is about one-third shorter than the tenth segment. On the hind margin of the ninth segment are six long spines (two dorsal, two dorso-lateral, and two ventro-lateral and two short ventral ones), on the tenth, six long and two short spines. The hind margin of the ninth tergite is furnished with a number of small sharp teeth (Fig. 8 *a*).

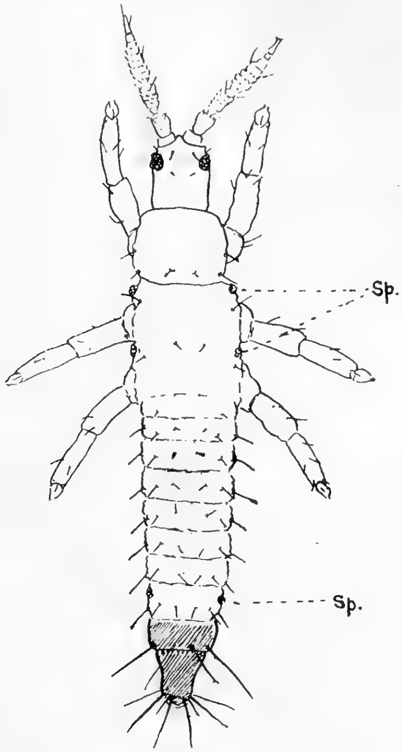


Fig. 9. Second stage larva. *Sp.* = spiracle.

The earliest date that I have found this stage was the 29th May 1914, the latest 29th July 1913.

Eight or nine days after hatching the larva casts its skin and enters on its second stage.

Second stage larva (Fig. 9).

This is about 1·6–1·8 mm. long, bright orange with the last two segments of the abdomen dark brown. The head and legs are now small compared with the much distended abdomen.

Description of second stage larva.

Measurements. Total length 1·4–1·8 mm.

Width of head across eyes 0·09 mm.

Length of ninth abdominal segment 0·08 mm.

Length of tenth abdominal segment 0·08 mm.

Antennae	1	2	3	4	5	6
length (μ)	23	40	50–60	64	17	32
width (μ)	32	29	28	25	17	12

Total length of antennae 0·20–0·24 mm.

Antennae (Fig. 7 *b*) six segmented, the third segment divided into five rings and the fourth into six. The fourth segment slightly narrower than the third.

The dark coloured ninth abdominal segment equal in length to the tenth segment. Near the hind margin of the ninth segment, in the position of the two most dorsal spines in the first larva, are two short transparent processes about 0·040 mm. long and rounded at the tip. On the tenth segment in a corresponding position are two stouter processes of about the same length, but gradually narrowing from the base to the apex which is sharp (Fig. 8 *b*).

The two stages are easily distinguished by the relative and absolute lengths of the ninth and tenth abdominal segments, and by the stout processes on these segments in the second stage which are only represented by hairs in the first.

Both stages of the larvae are found in the flowers and on the developing pods, less commonly in the terminal leaf cluster; as the pod grows and the petals fade and fall off they retire for shelter into the calyx, which forms a cup round the base of the pod. If the larvae have been sufficiently numerous to cause the pod to curl, they will be found chiefly on the concave surface. Should the pod crack or be pierced by other insects they may enter and produce on the inner surface the same characteristic 'silvering' of the surface.

In about six days the second stage larva is full fed. It then descends to the ground and goes beneath the surface to a depth of from three to twelve inches where in some suitable crack or crevice it remains for the rest of the year. There appears to be no attempt at the formation of a cocoon or pupal cavity.

The earliest date in which larvae in captivity have entered the earth was the 28th June (from eggs found on the 8th June), but larvae from eggs laid in May must descend before this. The total time from the laying of the egg to the descent of larva is about 24 days.

The larva remains without moving, in the position it has first taken up, throughout the rest of the summer, autumn and winter until the following spring when, sometimes during March, April or early May, it changes into the propupa or first nymph stage.

Pupal Stages.

The Propupa.

This stage—in which the first wing rudiments should appear and in which the antennae are still free—I have not yet seen. It apparently lasts a very short time. In 1913 the only specimen which survived fungus disease during the previous winter was still a larva when examined towards the end of April and by the middle of May had already reached the pupal or second nymph stage. In the spring of 1914,

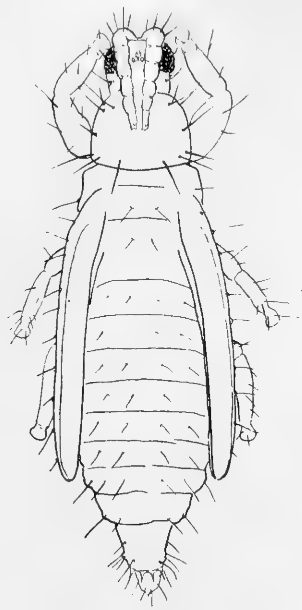


Fig. 10. Second nymph stage or pupa.

owing to an unfortunate misunderstanding, all my infected pots were thrown away by a gardener, but prolonged searching, both by hand and by means of the Berlese funnel, in the soil of a kitchen garden where peas had been attacked the year before yielded many larvae up till the 6th April and a single pupa on the 2nd May.

Pupa or second nymph (Fig. 10).

This stage is assumed during April or May. Normally it does not move from the original position, but when disturbed it walks sluggishly with frequent side to side rocking movements.

Description.

Colour. Head, thorax and abdomen shining orange-yellow. Antennae, legs and wing cases more transparent and almost colourless. The last two abdominal segments are also pale and semi-transparent, not dark as in the larva. The eyes are dark red-brown.

The *antennae* are laid back along the top of the head and reach to about the middle of the pronotum; between them the ocelli are visible. The wing rudiments reach to the seventh abdominal segment. The hind margin of the ninth abdominal segment is produced into several long tooth-like processes. Two long spines near each front angle of the prothorax, two near each hind angle, one near the middle of each lateral margin and one pair on the hind margin. Length 1·6 mm. (measured from life), broad in proportion.

The pupa darkens slightly before the emergence of the adult, but the latter is still pale and soft on escaping. It remains alongside the old pupal skin gradually hardening and darkening in colour for about two days, after which it works its way through the soil to the surface and is ready to start a new cycle of life and destruction.

The life-history of *K. robustus* as described above is very similar to that of *Taeniothrips* (*Euthrips*) *pyri*, the pear thrips. This latter is also single brooded, has two larval stages and spends the greater part of the year as a full fed larva in the earth beneath the infested trees. *Stenothrips graminum*, a species found on cereals in this country and on the continent, also hibernates as a larva deep in the ground (Kurdjumov, 1913).

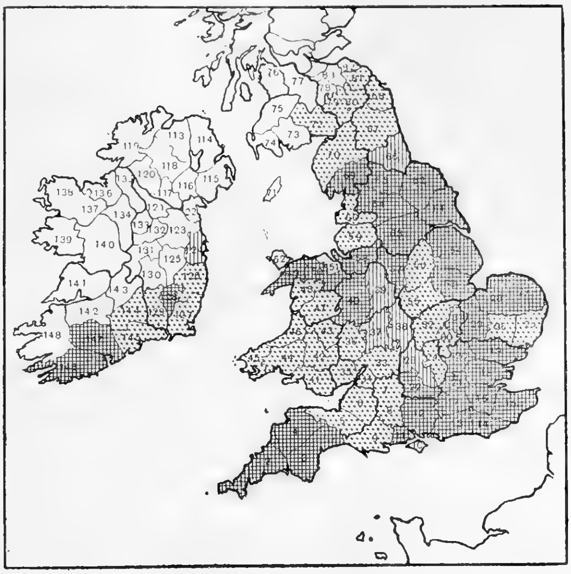
Distribution.

British Isles.

I have received records or specimens from twenty-nine counties in England, Wales and Ireland as shown in the map (Fig. 11) and below, but so far have not any record for Scotland. I have received bags of peas from a few localities in that country which were all quite free, and Professor Macdougall, of Edinburgh, tells me that he knows of no record of damage. It is probable, however, that it occurs at least in the south as I had but few correspondents, and, as has been mentioned above, the species occurs on the continent as far north as Sweden. Some of the records below are based on only a few specimens. The districts where it is numerous enough to do damage are chiefly in the south and east; I have, however, one record of damage as far north as Cheshire. The absence of records from counties in many cases only means that I had no correspondents in that district and must not be taken to imply the absence of the thrips from that district.

England.

Berkshire. Reading 1912.
Cambridge. Grantchester 1912, Wicken 1912, Cambridge 1914.
Cheshire. Hale* 1906, Neston 1912.
Cornwall. Lostwithiel 1913.
Derbyshire. Ludlow 1913.
Devonshire. Kingsbridge 1913.



⊙ Probable.
⦶ Reported.
⊕ Widespread. Causes damage.

Fig. 11. Present known distribution of pea thrips in the British Isles.

Durham. Hart and Blaydon-on-Tyne (Bagnall 1908).
Essex (Theobald 1907). Witham 1913.
Hampshire. Romsey 1912, Brockenhurst 1912.
Herts. Penshanger 1912, 1913, Amersham and Berkamstead 1908*.
Huntingdon. St Ives 1912.
Kent (Theobald 1906). Sittingbourne 1912, Shoreham, near Sevenoaks 1912, 1913, Maidstone 1913.
Lincoln. Burgh le Marsh 1913.

Middlesex. Richmond 1912.

Norfolk. Bessingham 1913.

Oxford. Walton Manor (Westwood 1880).

Shropshire. Near Shrewsbury 1913.

Stafford. Weston 1910*, Stoke-on-Trent 1910*.

Surrey. Reigate (Theobald 1906), Merton 1912, 1913, 1914.

Sussex. ?Crawley (Theobald 1900), Hailsham 1912*, Ditchling 1912.

Warwick. Warwick 1907*, Lupworth 1908*.

Westmorland. Kirkby Stephen 1912, Kendal 1912.

Worcester (Theobald 1906). Walford-on-Avon, Evesham and Worcester 1905*, Stourport 1907*, Redditch 1909*, Kidderminster and Studley 1910*.

Yorkshire. Malton 1913.

[The records with an asterisk * were kindly furnished by Mr W. E. Collinge.]

Wales.

Carnarvon. Pwllheli 1913.

Denbigh. Colwyn Bay 1913.

Ireland.

Carlow. Bagenalstown 1913.

Cork. Rochestown 1913.

Dublin. Glasnevin. I am informed that in 1897 a black active thrips injurious to peas appeared in the botanic garden; it is almost certainly this species.

Distribution abroad.

Bohemia (Uzel 1895).

France. Loiret, Darcy, Seine, Marseilles (Gaumont and Vuillet 1914).

Germany (Kirchner, von Schilling).

Italy (Buffa 1907).

Sweden. Stockholm, Ostergotland (Trybom 1899).

Nature and Extent of Damage.

The parts of the plant which suffer most from the ravages of this insect are the young leaves in the terminal shoots, the flowers and the pods. There is no record of the older leaves being attacked (cf. the American bean thrips below). In this country the terminal shoots appear to be infested only when the other situations are not available,

as on a very early attack (May) before the flowers are out, or later in the year on late sown varieties. It was this type of injury that Trybom (1899) describes as being most prevalent in Sweden, when the injuries caused whole terminal clusters to wither. Later when the flowers are

Fig. 12. Pods and flowers of peas damaged by thrips.

attacked these shrivel up and turn brown and in bad cases no pod at all may be formed. Usually, however, it is when the pods are small that the damage is most noticeable; they are sickly, undersized and curled and covered with very characteristic silvery brown areas where the larvae have been feeding. These areas are generally near the base

or the tip of the pod, but often, when the pod is much curled, the whole of the concave side may be 'silvered' (Fig. 12). The silvering is due to the presence of air in the outer cell layers of the plant let in by the sucking of the larvae.

The damage can be very extensive and occasionally the whole crop is spoiled. A correspondent at Sevenoaks, Kent, speaks of "several rows hopelessly ruined," while another at Reading had to give up growing beans because of the injury they suffered, but he unfortunately tried peas instead.

Food Plants.

The species seems to confine itself chiefly to the edible pea (*Pisum sativum*) and the broad bean (*Vicia faber*) and their varieties. Both field and garden crops may be attacked, but the latter seem to suffer more frequently. This may be due to the fact that in fields there is usually a rotation of crops, while in gardens the same crop is often grown on the same plot or quite close by year after year. I have not yet found this species on either sweet peas (*Lathyrus odoratus*) or scarlet runner beans (*Phaseolus vulgaris*), though Gaumont and Vuillet (1914) mention these as host plants in France. Thrips are often abundant on both plants, especially the latter, but, in my experience, always other species (chiefly *Frankliniella intonsa, Thrips tabaci, Thrips valida, Physothrips atrata*), and I am inclined to think that when damage is recorded on runner beans that it is due to one or more of these species and not to *Frankliniella robusta.*

I have also found this species on flowers of knapweed (*Centaurea nigra*) and both Uzel (1895) and Bagnall (1908) have taken it in flowers of *Scabiosa arvense.* Gaumont and Vuillet (1914) mention also *Medicago sativa, Cijuga reptans, Ecbalium elaterium* and *Coronilla vulgaris*; the two last do not occur in Britain.

Other Species found on Peas and Beans.

Aeolothripidae (*Antennae 9-segmented*).

Aeolothrips fasciatus. Common; easily recognised by its large size and banded black and white wings. Partly carnivorous, but also feeds on pollen and plant juice.

Melanothrips fuscus. Occasional; recognised by its large size and smoky black wings with very distinct veins.

Thripidae.

Frankliniella intonsa. See above (p. 227) for separation. Not infrequent, often common in scarlet runners.

Physothrips spp. (*atrata*, *vulgatissimus* (*pallipennis*)). This genus, which lacks the spine at the anterior angle of the prothorax, contains many species which are only identified with difficulty.

Thrips tabaci. Antennae 7-segmented; colour varying from greyish-yellow to brown; male lighter; common. I have found larvae and pupa of this species on peas.

Thrips physapus. Antennae 7-segmented; colour brown; not uncommon.

Thrips flava. Bright yellow; antennae 7-segmented. This species, which is sometimes common in the flowers, also lays its eggs in the stamen-sheath and other parts of the flower. The larva, however, has not the dark tail which is characteristic of *F. robusta.* It usually appears to be more common when the latter is absent, but I have never found it sufficiently numerous to do any great damage. It also occurs in scarlet runners and many wild flowers.

In the United States beans are much injured by *Heliothrips fasciatus*, which, however, unlike the present species, attacks chiefly the leaves and also spends all its life, including the pupal stages, openly on the food plant, there being several generations during the year. It hibernates as an adult (Russell 1912). Damage has also been reported caused by *Heliothrips phaseoli* (Hood 1912). We have three species of the genus *Heliothrips* in England, but all are confined to greenhouses; there would therefore appear to be little danger of the American species establishing itself in this country.

Kirchner (1890) mentions a species, *Thrips pisi* (Kubler), which would appear from its name to be connected with peas. I have, however, been unable to find the original or any other reference to this name.

NATURAL ENEMIES.

Fungus. There was very great mortality of hibernated larvae owing to a fungus which attacked them even in very dry conditions. The hyphae radiated out from the attacked larvae and any other larvae close by became infected in a short time.

Coccinellidae. I was able to feed larvae of *Coccinella bipunctata* in captivity on larvae of the pea thrips, but in the wild state I have never

found the ladybird larvae in the infested flowers, and believe that they exert little, if any, controlling influence.

Chalcidae. Vuillet (1914. ii) has recently described a Chalcid *Thripoctenus brui* n.sp., belonging to the Tetrastichinae, which he found among the larva of the pea thrips at Darcy, Aisne, France, in July 1913. Although he has not actually bred this Chalcid from the larvae, yet there is little doubt that it does parasitise them as it was always found in conjunction with them, and further the only other known species of this genus (*T. russelli*) is parasitic on *Heliothrips fasciatus*, a species which, as mentioned above, is injurious to beans in the United States.

Thripoctenus russelli, or a closely related species, has been taken in England by Bagnall (1914), but I have found no species of this genus as yet among the pea thrips in this country. I have, however, found on several occasions in different localities Chalcids among larvae of the pea thrips, but cannot be certain whether they have any connection with these or not. M. Vuillet has kindly offered to let me have some living specimens of his species if he finds it in sufficient numbers, and an attempt will be made to establish it here.

Other controlling Factors.

Weather. Wet weather always causes great mortality among thrips and also causes the plants to grow more rapidly. In this species, unfortunately, the rain has less effect than usual owing to the sheltered position of the insect in the flowers. However, several correspondents mention that the attack is greatest in dry weather and is lessened by a heavy shower of rain.

Soil. The pea thrips is most prevalent on light soils. In the majority of cases reported to me the soil has been light or gravelly, and a correspondent at Shoreham, Kent, states that the damage is always worse in the village where the soil is light than at Highfield near by where the soil is heavier. It is probable that the conditions in a light soil are more suitable for the hibernating larvae.

Varieties and time of planting. No variety of pea or bean is immune to the attack, but the earlier sown plants usually escape severe damage. As the females lay their eggs chiefly in the stamen-sheath of the flowers, any plants which have passed the flowering stage before the adults become common escape almost entirely. Actual varieties of pea mentioned as having suffered less severely in infested districts are 'Gradus' (an early variety), 'Primus,' and 'Autocrat,' but a careful examination of nearly forty varieties at a seed testing ground at Witham,

Essex, in July, 1913, gave no indication of resistance, except that due to time of planting. In *Report on Field Experiments*, 1912, East Anglian Institute of Agriculture, Chelmsford, it is stated that 'Telegraph' was destroyed by thrips, while 'Gradus,' 'Essex Star,' 'Alderman' and 'Blue Seedling' gave good crops.

Artificial Control.

The habits and life history of this insect make the application of remedial measures of great difficulty. Sprays will not reach the adults or larvae in the flowers, and during the winter the great depth to which the larva descends (they have been found in the wild state more than ten inches below the surface) makes the application of gas lime or soil fumigants of doubtful value. In March of this year numbers of larvae were found deep down in a plot of soil which had been heavily limed last autumn.

When plants are attacked late the larvae, however, are often found in numbers feeding openly on quite large pods. At such a time spraying with any contact spray (soft soap, rosin, etc.) should give good results. On a small scale the following has been found successful

Stock solution

Water	1 qrt.
Soft soap	3 oz.
Tobacco powder	3 oz.

The whole boiled for a short time and diluted for use about one part to twenty of water.

When only a small area is attacked fumigation of the soil during the winter with carbon bisulphide, gas lime, creosote, or such trade products as vaporite or creol should give good results, provided that it is done to a sufficient depth. Experiments are now in progress to test carbon bisulphide-oil emulsion recently described and which it is hoped may prove satisfactory.

Whenever possible a rotation of crops should be practised and peas and beans grown as far as possible from the areas attacked in the previous year.

Traps employing *benzaldehyde*, *anisaldehyde* and *cinnamyl aldehyde* as attractive agents, as described by Howlett (1914), were tried and found to be of no use. These aldehydes have no attraction for this species of Thysanoptera.

The burning of the pea sticks during the winter, frequently recommended, is of no use. Many thrips may be beaten from the sticks, but not this species (chiefly *Limothrips cerealium* and species of the sub-family *Tubulifera*).

Notes on Methods of Collecting and Breeding.

Thrips for identification purposes are of no use when dry. They should be collected into 70 % alcohol, or a mixture of 70 % alcohol and glacial acetic acid in equal parts. In the latter case they must be transferred after a few hours into 70 % alcohol. The latter method is better for larvae as they are less distended than in the alcohol alone. For critical examination they must be cleared and mounted in balsam as a microscope preparation. I find Grübler's 'Turpineol' the most satisfactory clearing agent as it leaves the insects sufficiently pliable to allow of the moving of the wings and legs into suitable positions.

Living specimens of pea thrips have been obtained from all over the country in parchment bags closed with slide-on paper fasteners. These bags are sent out in suitable boxes with instructions to fill with flowers or pods placed in the bag straight after picking. In this way material was obtained from friends and others who knew nothing of entomology, many not even knowing by sight the thrips in question. Many other thrips and insects were found in the bags in which the plants would keep fresh for four or five days, and the method appears to be worthy of wider application. Most of the bags I used were supplied by Messrs Miller and Sons, Renfield Street, Glasgow, but the bags sold for 'paper bag cookery' also answer quite well. They should, however, be as transparent as possible as some idea of the contents can then be got by holding up to the light before opening.

Eggs were obtained, and larvae bred in small glass tubes plugged with cotton wool. Frequent changing was necessary or the moisture which condensed on the sides of the tubes was a great danger, and the sun should on no account be allowed to shine directly on to the tubes. Larvae were hibernated in beakers filled with soil and in flower pots sunk in the ground. They were also obtained in soil during the winter with Berlese's 'Insect Funnel' which, by means of warmth, extracts all the small insects from the soil which is placed in a sieve at the top[1].

[1] I have given a short account of this in the *Entomologist*, XLVI, 1913, p. 273.

SUMMARY.

(1) Peas and beans in England and Western Europe are damaged by a thrips *Kakothrips robustus* (sub-order *Terebrantia*, family *Thripidae*).

(2) The adults appear from May to August; males only in the earlier part. The eggs are laid chiefly in the tissue of the stamen sheath. They hatch in about nine days. The larvae are orange-yellow with the last two abdominal segments dark brown. There is one moult. The second stage when full fed (about 24 days from the laying of the egg) descends into the ground to a depth of from three to twelve inches.

(3) The full fed larva remains in this position till the following spring when the two pupal stages are passed through and the adult emerges. There is only one brood each year.

(4) The damage is greatest on light soils. No varieties are immune, but early sown plants are less damaged. A chalcid parasite, *Thripoctenus brui*, has been recorded from France, but has not been found in England.

(5) Artificial control is difficult. Spraying is only of use when the larvae are feeding openly on large pods. Soil fumigation during the winter should give good results, but must be done to a sufficient depth.

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THE APPLE SUCKER, WITH NOTES ON THE PEAR SUCKER.

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(With Plates XVII, XVIII and 21 Text-figures.)

CONTENTS.

Introduction.

The following pages contain an account of a study of the apple sucker made by Mr Awati at Acton Lodge, Brentford, during the summer of 1913. The fact that the life-history of apple suckers occupies one year implies that in one season no stage repeats itself, and Mr Awati could not repeat or check the observations he made.

The most notable point brought out is perhaps the nature of insecticides; so much spraying is done against apple sucker with so little result, simply because the fruit-grower knows no way of checking his results, that the method here adopted should be of interest to fruit-growers generally. It is quite simple and does give a real check on the results one is getting.

Mr Awati left for India and had not time to fully revise the text, so I have done so. I also express herewith our acknowledgments to Sir John Wolfe-Barry, whose generous provision of the studentship made possible Mr Awati's paper on the Mechanism of Suction in *Lygus pabulinus* (*Proc. Zool. Soc. London*, 1914, p. 685) and the present paper. I hope that the work on apple sucker will be of value to fruit-growers in England, and I think the method of checking it is a real advance on anything hitherto used in this country.

H. M. LEFROY.

The Apple Sucker (*Psylla mali*).

I. *Egg to Larva.*

(*a*) *Distribution of Eggs* (Fig. 21). (Black dots on twigs represent eggs of *Psylla mali.*) The eggs are laid singly on the twigs of the apple trees. They are never found in clusters or groups, but on the contrary they are irregularly distributed on the twigs, which are chosen according to their age. It seems that new twigs (of the first year's growth) are chosen by the female on which to lay the eggs. In some cases I have found that the eggs are deposited on one side while the other is tolerably free from them. It is possible that light may have something to do with this kind of deposition. The eggs are found along the scars (on a twig) left on the leaf petioles.

(*b*) *Description* (Fig. 1). An egg of *Psylla mali* is oblong, tapering to both ends. It is sculptured into fine little circles. It is pale white when laid, but begins to change colour when it nears the hatching season, then it becomes distinctly pale brown or reddish. At one end there is a long stalk which hangs free in the air, while at the other there is a sucker-like expansion which glues the egg to the twig. Its position on a twig is such that its long axis lies parallel to that of the twig.

(*c*) *Hatching.* The eggs begin to hatch when spring sets in. If the weather is warm before the spring they may hatch earlier, but generally the larvae begin to come out in the last week of March. I have seen an egg hatching on March 23rd; the hatching may go on for some time, until the last week of April.

(*d*) *Mechanism.* The eggs are split up longitudinally (Fig. 2). It seems that there is some mechanism, which is shared partly by the egg and partly by the larva. The spot where the larva comes out is provided with minute teeth which from either side form a dovetailing

device (Fig. 3). At the same time the larva is provided with an egg-breaker on the front part of its head. This egg-breaker consists of some stout spines attached to the flat part of its head. The spines push the dovetailing device apart, and the larva crawls out. There are a number of spines both dorsally and ventrally which keep the sides of

Fig. 1.

Fig. 2.

Fig. 3.

the egg apart, while the larva is creeping out. The following is a complete diary of a larva hatching out:

27. 3. 13.

10.30 p.m. The larva began to come out.

11.30 p.m. It was completely extruded from the egg but was still attached to it.

11.50 p.m. Sitting at the opening of the egg, moving its antennae and thus taking rest after a great deal of trouble.

2.30 a.m. Quite free from the egg and walking about.

The larva is completely yellow when it comes out and the egg-shell is opaque white. Thus it seems that the change in colour of the egg is due to the larva which becomes brown or reddish as its time for hatching out is nearing.

(e) *Behaviour of the first larva.* The larva, after resting a while, begins to crawl up towards the apical bud of that twig. It has a pair of well-developed antennae, the last segment of which is drawn out and

is provided with two bristles. The larva is moving its antennae and is possibly attracted to the bud by a kind of chemotropism; otherwise it is impossible to say why the larva should crawl up towards the bud, which at this time is also sprouting. It sometimes happens that the bud, on that twig, is not yet opened. In that case the larva is at a standstill. It can live without food for two or three days, at the end of which period it succumbs to death. But on the whole, the time for the larva to hatch and the bud to blossom is so finely adjusted, that the former has not to wait for the latter.

II. *Summary of the Life-History.*

There are in all five instars, the last of which is here called the "Nymph," from which the adult insect emerges. Larvae were bred artificially in the experimental house. The method of breeding them was as follows: tender short apple twigs were cut and embedded in

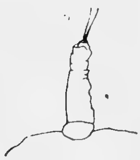

Fig. 4.

Fig. 5.

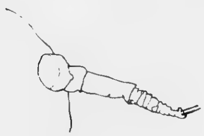

Fig. 6.

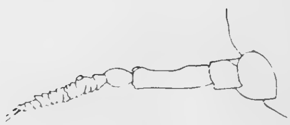

Fig. 7.

wet silver sand in a museum jar, the top of which was covered with a thin piece of muslin. The wet sand enabled the twigs implanted in it to keep fresh for two or three days, at the end of which time they were replaced by fresh twigs. The larvae were carefully picked from the old twigs and placed gently on new ones. Thus it was possible to study them very closely. The temperature of our room was equable and was somewhat higher than that outside. Small apple trees were used for checking the period of each stage, and it seems that this artificial method has no appreciable effect on the life-history of these insects.

The following table shows the period taken by each stage for its moult.

1st instar (Fig. 4).

	On twigs in the sand.		On plants outside.
1.	23. 4.—30. 4. ..	.. 8 days	
2.	21. 4.—28. 4. ..	.. 8 days	
3.	25. 4.—ql. 5. ..	.. 7 days	

2nd instar (Fig. 5).

1.	18. 4.—25. 4. ..	.. 8 days	
2.	20. 4.—27. 4. ..	.. 8 days	
3.	26. 4.— 3. 5. ..	.. 8 days	

There was no time for checking the period of these instars.

3rd instar (Fig. 6).

	On twigs in the sand.			On plants outside.	
1.	29. 4.—6. 5. ..	.. 8 days	1.	26. 4.—3. 5. ..	.. 8 days.
2.	28. 4.—4. 5. ..	.. 7 days	2.	29. 4.—6. 5. ..	.. 8 days.
3.	25. 4.—1. 5. ..	.. 7 days	3.	26. 4.—3. 5. ..	.. 7 days.
4.	26. 4.—3. 5. ..	.. 8 days	4.	29. 5.—5. 5. ..	.. 7 days.
5.	30. 4.—7. 5. ..	.. 8 days	5.	29. 4.—6. 5. ..	.. 8 days.
6.	25. 4.—1. 5. ..	.. 7 days	6.	1. 5.—7. 5. ..	.. 8 days.
7.	24. 4.—1. 5. ..	.. 8 days			
8.	26. 4.—3. 5. ..	.. 8 days			
9.	27. 4.—3. 5. ..	.. 7 days			
10.	26. 4.—3. 5. ..	.. 8 days			

4th instar (Fig. 7).

	On twigs in the sand.			On plants outside.	
1.	1. 5.—11. 5. ..	.. 12 days	1.	3. 5.—12. 5. ..	.. 10 days.
2.	30. 4.—10. 5. ..	.. 11 days	2.	5. 5.—13. 5. ..	.. 9 days.
3.	1. 5.—11. 5. ..	.. 12 days	3.	29. 4.— 9. 5. ..	.. 11 days.
4.	3. 5.—12. 5. ..	.. 10 days	4.	1. 5.—10. 5. ..	.. 10 days.
5.	29. 4.—13. 5. ..	.. 15 days	5.	5. 5.—13. 5. ..	.. 9 days.
6.	30. 4.—10. 5. ..	.. 11 days			
7.	6. 5.—15. 5. ..	.. 10 days			
8.	3. 5.—12. 5. ..	.. 10 days			
9.	30. 4.—10. 5. ..	.. 11 days			
10.	6. 5.—15. 5. ..	.. 10 days			

5th instar or "Nymph" (Fig. 8).

	On twigs in the sand.			On plants outside.	
1.	9. 5.—21. 5. ..	.. 13 days	1.	9. 5.—18. 5. ..	.. 10 days.
2.	11. 5.—23. 5. ..	.. 13 days	2.	12. 5.—22. 5. ..	.. 10 days.
3.	10. 5.—23. 5. ..	.. 14 days	3.	13. 5.—22. 5. ..	.. 10 days.
4.	10. 5.—23. 5. ..	.. 14 days	4.	13. 5.—22. 5. ..	.. 10 days.
5.	12. 5.—24. 5. ..	.. 13 days			
6.	13. 5.—24. 5. ..	.. 12 days			
7.	8. 5.—20. 5. ..	.. 13 days			

At this time the plants were transferred to the frames, where the heat was greater than outside. The variation in the time may be due to this fact.

6th or adult stage (Fig. 9). June to November.

There were many larvae bred from beginning to end. But I had to replace those that died in the course of breeding. There are peculiarities of each instar by means of which the different instars can be distinguished. These peculiarities will be described below.

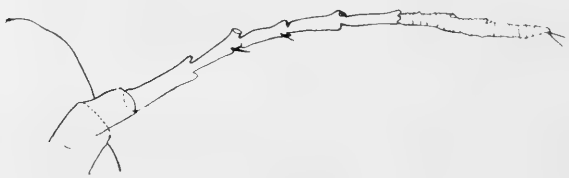

Fig. 8.

Fig. 9.

III. *Description of the Instars.*

(*a*) *General description.* (i) *Colour.* A larva of each stage passes through the same cycle, though it is growing bigger in size. It is bright yellow when it hatches out or has moulted. The colour gradually changes to yellow-brown, or in some cases distinctly reddish. This change in colour may be due to exposure to atmosphere. But there is a complete change of colour in the nymphal stage, when it becomes entirely green. The larva of the fourth instar changes its colour from brown to pale green as it matures for the fourth moult.

(ii) *Secretion* (Fig. 10). The larvae of these insects are unmistakeably recognised by their secretion. All the larvae, including the nymphs, have opaque white secretion, a long thread of which is hanging out from the hinder portion of the abdomen. This thread consists of a central core of translucent liquid covered externally by the whitish material which prevents its exuding and thus wetting the surface of a leaf. The larva begins to secrete as soon as it hatches out or has moulted. The thread in some cases reaches a great length; at the end there is a big knob-like swelling. If the thread is pricked, the translucent liquid exudes and wets the surface. This secretion is of a waxy nature and is soluble in alcohol. Besides this big thread issuing from the anus, there are small spine-like threads projecting from the extremity of the abdomen. They are shining and seem to change colour, which is not their intrinsic

property as some investigators think, but it is due to the refraction of light; this is clear since the colour seems to change as one sees it from fresh points of view.

Fig. 10.

(iii) *Heart-Shaped Organ* (Figs. 12, 13, 14). (*a*) *External appearance.* Every larva has this characteristic organ, which is cordate in shape (Fig. 12) and is bordered with several rows of big pores, besides which there are also minute pores in many tiers inside the boundary.

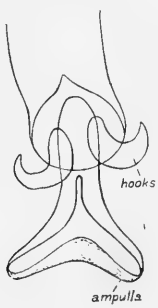

Fig. 11.

In the centre of this organ there is a peculiar-shaped structure which is due to the invagination of chitin. Just above the notch of this organ is an aperture presumably functioning as the anus or the opening of the waxy glands. On either side of this opening there are two

strong spines which may direct or support the thread of secretion alluded to above.

(*b*) *Internal structure* (Figs. 13, 14). Inside this heart-shaped organ are situated two kinds of glands both of which are of a waxy nature. The larger of the two finds its exit through the aperture mentioned above. This is demonstrated by the longitudinal section (Fig. 13). It is a big coiled structure occupying the whole of the abdomen of a larva and secreting the big thread of wax mentioned above. The other consists of small glandular cells opening out through those pores referred to already. They secrete fine, shining, small spine-like threads

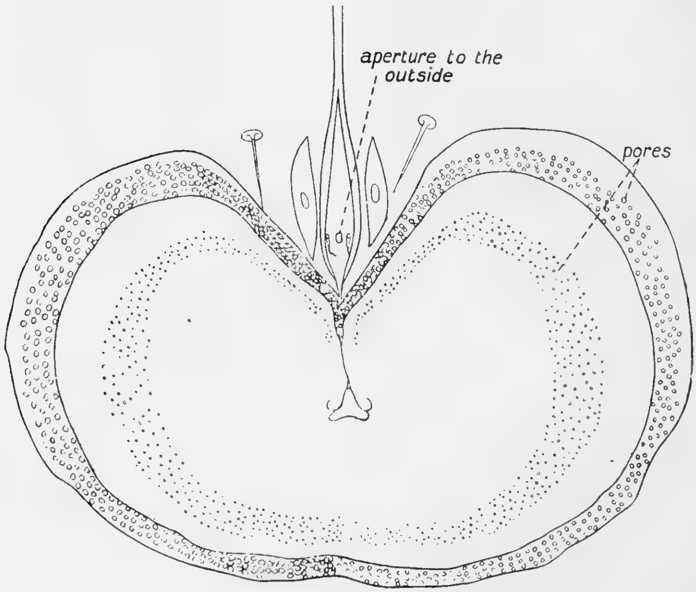

Fig. 12.

projecting from the extremity of the abdomen. This structure will be clearly understood from a transverse section (Fig. 14). This organ with the glandular structures is left behind when the nymph moults to the adult insect. There is not a trace of these structures in the adult, which does not secrete honey-dew.

(iv) *Wing Lobes.* These begin to appear in the third instar. In the second instar their places on the meso- and meta-thorax are already marked, but in the third there are small protuberances in these places. They become well developed in the fourth instar, while in the nymphal stage they are broad and elongate, lying at the sides. There are also small

vestigial nervures on them, though the whole appearance is entirely different from the wings of the adult insect.

(v) *Claws* (Fig. 11). It is not necessary to describe the legs of a larva in detail, inasmuch as it does not differ from those of any ordinary insect. But their extremities are very interesting. There are two strong curved spines, in the midst of which there is a sucker-like organ which has

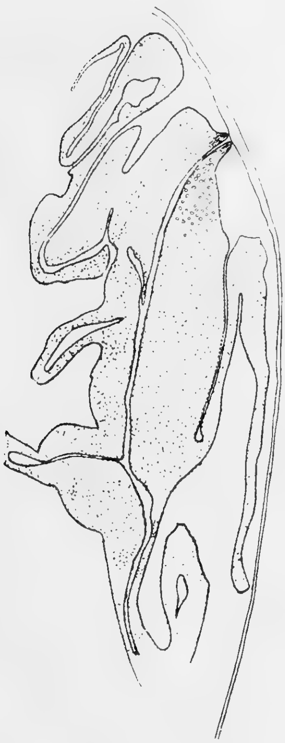

Fig. 13.

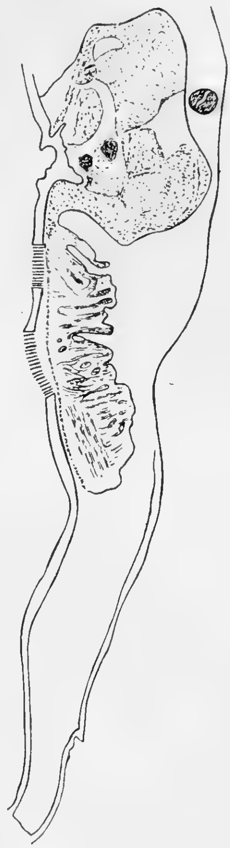

Fig. 14.

a big hollow cup (ampulla). These claws are adapted for the larval life as the larva has to crawl on the waxy and slippery hairs of the apple-buds. The ampulla enables the larva to fix its leg very firmly on the surface, while the spines may help the larva in locomotion.

(vi) *Eyes.* The larval eyes are red or reddish in hue, though in the nymphal stage the colour changes to dark green, while in the adult the eyes are distinctly black.

The larvae are distinguished from stage to stage; the distinction being in the increase of the number of segments of the antennae. The first and last segments seem to remain unchanged, and the rest are intercalated from instar to instar. The external appearance of the last segment with its two bristles is very characteristic through the whole life-history of *Psylla mali.*

The following table will give the characteristic differences of the antennae of each instar:—

Instars	No. of segments
1st instar (Fig. 4)	2
2nd ,, (Fig. 5)	3
3rd ,, (Fig. 6)	4
4th ,, (Fig. 7)	5
5th Nymph (Fig. 8)	7
6th Adult imago (Fig. 9)	9

IV. *Habits of the Young Insects.*

A description of the habits of the larvae or the insects in general can never be too important nor too detailed, since the basis of insecticides is founded on that. The more we know of the habits of an insect, the easier does it become to kill it.

(i) *Chemotropism.* The larvae are positively chemotropic, their antennae are very well developed, especially the last segment with its two bristles. The first larva, as soon as it is hatched, crawls towards the apical bud of the twig. It is moving its antennae in the air. The larva seems to be attracted by a smell emitted by the bud, to which smell we seem to be insensible. The same phenomenon is repeated in other instars, which are all attracted to the buds by means of some chemical substances.

(ii) *Heliotropism.* All the instars except the nymphs are negatively heliotropic. They avoid light and are always found in the dark recesses of the bud. As soon as they are brought to daylight, or an artificial light (electric) is brought to bear upon them, they try to avoid it. It is this habit which enables them to find the tender leaves of the buds inside. The nymphs, on the other hand, are positively heliotropic. As soon as the fourth instar moults for the nymph, the latter leaves the darkness of the bud and comes to live on the open under surface of the leaf. This change of habit may be beneficial to an imago emerging from it, as the latter must have an open surface to fly.

(iii) *Thigmotropism.* This is peculiar to these larvae, except the nymphs. They are positively thigmotropic, *i.e.* they react positively

to pressure. The leaves of the buds are pressed against each other and the larvae like to be among those closely packed leaves. This habit combined with (ii) is very advantageous to them, since both habits enable the larvae to get at the most tender leaves of the buds. The nymphs, on the contrary, are negatively thigmotropic. They avoid being pressed together and come to live free, uncrowded on the open surface of the leaves.

(iv) *Gregariousness.* All the instars, except the fifth, are gregarious in habit. They are found crowded together, and try to come together however much they may be separated from one another. I have tried many cases when the larvae were put separately on different buds of the same twig. On the second or at most the third day they were found to be together. This gregarious habit of the larvae is extremely useful since one can kill all of them in one lot. The nymphs, however, are never gregarious. They are always separated from each other and try to avoid the neighbourhood of other larvae and nymphs as well.

(v) *Powers of endurance.* The larvae can live without food for two or three days, after which they collapse and die. The fact that they can thus exist temporarily is very beneficial to the first instar, as it may not immediately find a fully-opened bud on its twig.

(vi) *Situation.* The larvae are always found in the recesses of the buds. They are rarely found outside, except in the nymphal stage, when they are found on the under surfaces of the leaves. The buds infected by them can easily be recognised. They are all covered with the waxy threads hanging down like icicles. The nature of the threads has already been described above. The position of the larvae in the bud seems to be fairly constant. The head is turned away from the growing point of the apex of the bud and the abdomen is turned towards the apex. In the case of nymphs, the position is very indefinite. The larvae, when sucking, press themselves down against the surface of a leaf and the whole body seems to be heaving up and down as the stylets are withdrawn or thrust into the leaf. The length of the stylet is enormous. In all stages they are twice or thrice as long as the whole body.

V. *Effects produced by the Larva.*

Psylla mali is most dangerous to apple trees in its larval stages. While in the adult, it does practically no damage. As described above, the larvae are gregarious in habit and plenty of them are thus found in

a single bud. Each larva thrusts its stylets deep into the tissues and begins sucking the juices. The suction-pumps of the larvae are at work night and day sucking the juices of the bud until it completely dries up. The leaves become brown, as if they were frost-bitten, wither, and drop down one by one. The buds, both floral and foliage, are thus destroyed wholesale and the apple trees cannot, of course, bear any fruit. If there is any remedy to be applied, it should be applied when the insect is in the larval stages. It seems that the growth of the buds (floral and foliage) runs parallel with the development of the *Psylla mali*. Soon after the flowers are set, *Psylla mali* is in the adult stage, when it does no damage. There are other effects produced indirectly by these larvae. They soil the bud-leaves by the secretion of waxy substances when the threads of secretion are broken up. The translucent stuff of the core exudes and covers the surface of the leaf. Particles of dust get glued to the leaf. In fact the wax forms an impervious layer over the surface. This may interrupt free transpiration of the leaves, which may thus be smothered and suffer. It is, however, curious that no fungus is seen growing on the leaves thus wetted by the larvae. This effect is not universal and may only be found in some places.

VI. *The Adult.*

(*a*) *The external sexual differences.* (i) Both sexes seem to be alike in general appearance, though there is an obvious difference in the shape of the genitalia. In the male they are curved and turned upwards, while in the female they are straight and pointed and lie concealed in the upper and lower anal segments. Their anatomical description in the female only will be given below in the reproductive system.

(ii) *Colour differences.* The colour of the male seems to be brown or at the most pale green; it is never green nor deep green; while the females are nearly always deep green. The colour in both the sexes changes with the age of the insects, but it never becomes uniform in both the sexes.

(iii) *Abdomen.* The abdomen of the female seems to be broader when it is fertilised, while that of the male is very narrow and tapering.

(*b*) *The proportion of the sexes.* In the beginning of this investigation it was suspected that there was parthenogenesis among these insects. If so there would be a disproportion among the sexes—the females outnumbering the males. To solve this question the adult insects were caught at different times from the period they emerged from

the nymphs to the time when they laid eggs. The results of those different catches are given below:—

Time	Female	Male
May 27, 29	40	36
June 2	39	51
16	34	32
19 and 24	97	99
July 2	44	38
9	36	46
Aug. 12	49	47
22	24	23
	363	372

It seems clear that there is no great disproportion in the sexes and no reason to anticipate parthenogenesis.

Habits of the Adults.

(*a*) *Change of colour.* The adults, both male and female, undergo some change in colour as they grow older. The uniform brown, pale green, or deep green gives place to a tinted pattern of the same. Some females of reddish brown have been found.

(*b*) *Feeding habits.* The males and females sit on the leaves—either on the upper or lower surface. They are very harmless in this stage, though they produce certain characteristic symptoms of their presence. They suck the juices of those leaves, which become marked with very minute circular white spots. These spots seem to increase in size and afterwards the spotted surface disintegrates and small holes are formed. Thus the presence of *Psylla mali* in the adult stage can easily be recognised. Another class of insects (Jassids) also produces white spots, but these can be easily distinguished from those of *Psylla mali* by mere observation.

(*c*) *Flight.* They are rarely seen on the wing unless disturbed. Then they seem to jump forward with their hind legs and take a short flight—from leaf to leaf or twig to twig.

(*d*) *Habitat. Psylla mali* seem to choose the under surface of leaves, though they are sometimes found on the upper. In the adult stage they are not confined to apple trees alone, but seem to migrate to different plants interspersed with the apples. They are found on gooseberry bushes, pear trees, plums, etc., besides apple trees. This migration may explain how the infestation is carried from one orchard to another, because their powers of flight would not sustain them in direct migrations from one apple-orchard to another.

VII. *Tracheal System* (Figs. 15, 16).

From the economic point of view none of the internal organs of an insect is of more importance or deserving of more attention than the tracheal organs. They constitute the chief medium through which a contact-poison insecticide acts. Prof. Lefroy has proved this point by his experiments on meal worms. The tracheal system differs in different insects, as also in the larva and the imago of the same insect, specially with regard to the way the respiratory organs open to the exterior. In some insects the spiracles lead directly to the tracheae, while in others there are various modifications for closing and opening the mouths of the tracheae. This difference in the arrangement of the

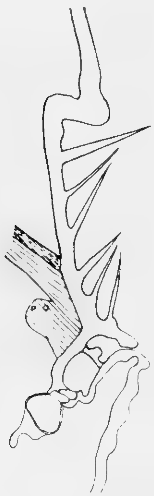

Fig. 15.

Fig. 16.

spiracles and the tracheae may explain why a certain insect with simple tracheae succumbs to an insecticide more easily than others with modifications of the tracheal apparatus. In *Psylla mali* there are two kinds of trachea, one in the imago and the other in the larvae, including the nymphs.

(i) *Tracheal system in the imago* (Fig. 16). It is of the simplest. The outer integument is invaginated to form a spiracle which leads directly to a tracheal trunk. There is a structure in the spiracles which may function as a strainer of the air which is sucked through the spiracles. The structure of a spiracle of this kind may be easily understood from the figure.

(ii) *Tracheal system in the larvae* (Fig. 15). This system is extremely complex. There are various devices between the external opening and the tracheal trunk, which are:

(*a*) *The spiracles* (three on the abdomen and two on the thorax) are situated in a pit which is covered over with long hairs.

(*b*) *The external lid of the spiracle.* This is formed by a thick process which lies across the spiracle.

(*c*) *The closing apparatus.* It consists of thickened chitin stretching from the one side of the tube to the other. It is acted upon by the spiracular muscles which are attached to this apparatus. When these muscles contract, this transverse bar of chitin is pulled apart and the spiracle is opened.

(*d*) *Atrium.* Below the closing apparatus is a cavity which communicates with the main tracheal trunk.

The simple structure of the spiracle of the adult and the more complex structure of that of the young lead one to infer the adult will react more readily to an insecticide and this is actually the case. In experiments with insecticides, I found that the adults died as soon as the emulsion reached them, whereas the young struggled for some hours before succumbing. The progress of the insecticide into the adult is unchecked, whereas it is obstructed in the larva; it has, in the latter case, to pass the hairs before it reaches the spiracle, and it cannot then pass the closing apparatus till paralysis is set up, opening the valve and giving it unrestricted entrance to the tracheae.

VIII. *Reproductive System* (Figs. 17, 18, 19, 20).

(i) *The reproductive system* does not begin to develop until the adult stage is reached, though the indication of this system is early seen in the fourth and fifth instar, in which the external sexual differences begin to be visible; the males (the larvae which are going to become males) being short and the females longer.

(ii) *Coupling.* Coupling begins in the first week in June, but the eggs are not laid until September. The coupling members lie side by side dorso-ventrally, their heads being turned in the same direction. This is a very characteristic position of these insects.

(iii) *The reproductive organs of the female.* Primary. These consist of the following parts (Figs. 18, 19, 20):

(1) *Ovaries* (Fig. 19). They consist of small egg-tubules, from

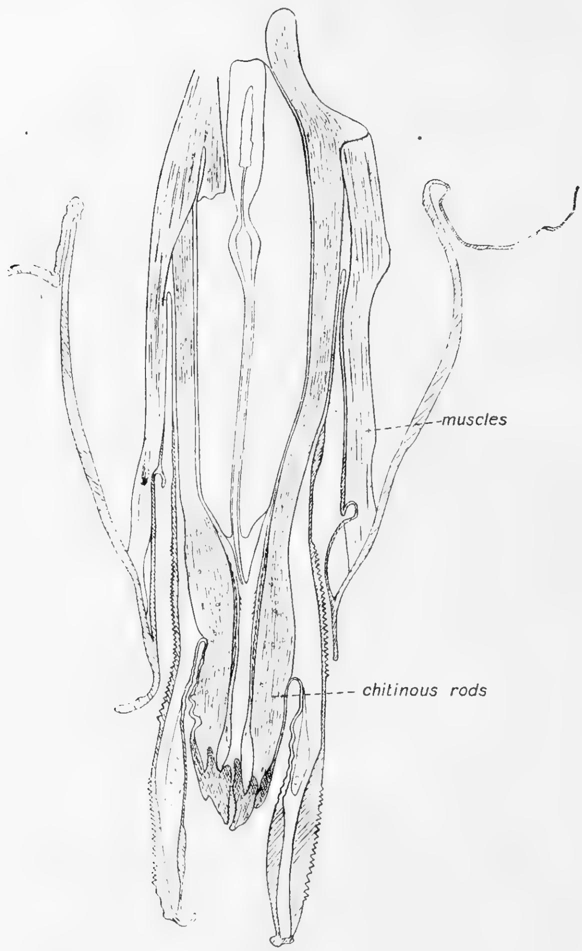

Fig. 17.

Fig. 18.

Fig. 19.

eight to nine on either side; each tubule is composed of three or more cells. Each tubule ends in a cell full of nuclei which may give rise to the egg-nucleus. This kind of ovary has

(2) *Oviducts* (Fig. 18). There are two oviducts, one on each side. The ovarian tubules open into them, and they in their turn open into the vagina as a single duct. The oviducts are coiled and nearly bent upon themselves on their way to the vagina, with which they communicate ventrally after they have formed a common duct.

(3) *Vagina* (Fig. 20). This is a single median muscular sac, communicating externally through the ovipositor. There are circular muscles which seem to be very powerful.

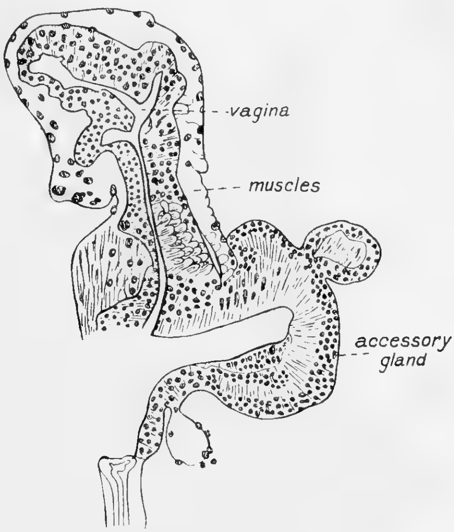

Fig. 20.

(4) *Accessory glands* (Fig. 20). They open into the distal part of the vagina. They consist of two kinds, one larger than the other, the smaller opening into the larger. At the entrance into the vagina there are muscles which regulate the opening of these glands.

(5) *Spermathecum* (Fig. 18). There is a single median spermathecum lying ventrally below the vagina, and the oviducts. It opens into the distal part of the vagina by a duct which runs dorsalwards. This spermathecum is used for storing the sperms. The vagina changes in structure distally and opens into the tube formed by the ovipositors.

Secondary characters. The ovipositors (Fig. 17). This structure is

formed by the invagination of some of the posterior segments of the abdomen. They consist of the following parts:

(1) Supra-anal segment.
(2) Infra-anal segment.
(3) Chitin rod on each side, ending distally in a pointed structure.
(4) Muscles attached to these chitinous rods.

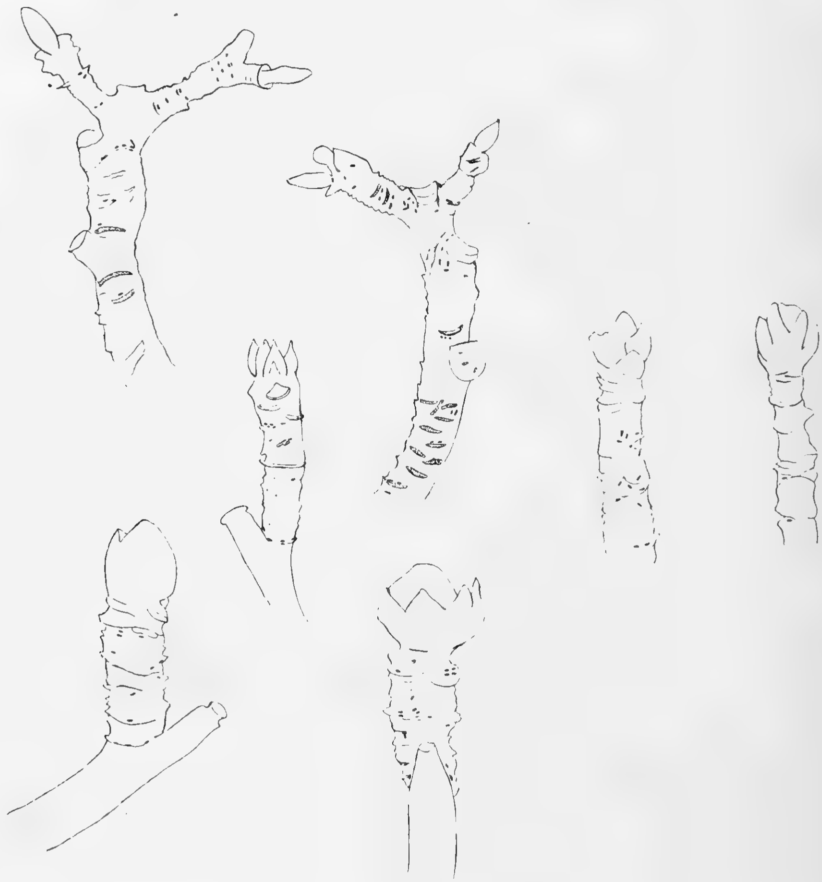

Fig. 21. The Eggs on Twigs.

(iv) *Oviposition.* The points of the chitinous rods, between the vagina opening, are concealed by the supra- and infra-anal segments. When the muscles, which are attached to the proximal ends, contract, the chitinous rods are pushed forward and the points project further than the anal segments which are applied to the surface of the twig. The egg, which is pushed forward by the circular muscles of the vagina,

enters the cavity formed by the ovipositors. Distally there are recurved minute hairs which prevent the egg from going back. One egg is laid at a time.

(v) The maximum number of eggs produced by a female in one case was 30, in another 37.

(vi) *The egg-laying season.* This is very short and only extends over a week. The females began egg-laying early in September. By the middle of the month the season was over.

(vii) The males and females seem to outlive this egg-laying season for some time. They are found as late as October and they appear to die towards the end of that month. In November I could not find any specimen of the *Psylla mali.*

IX. THE PEAR SUCKER (*Psylla pyricola*).

This insect is the most important pest of pear trees on the Continent and in America. Unfortunately, it has recently been found in the United Kingdom, and was reported last year by Prof. Theobald, of the Wye Agricultural College. This insect has the same life-history as *Psylla mali,* but there are many important differences and features which make this insect more formidable than *Psylla mali.*

(1) *Eggs.*

They are elliptical and narrow. Their colour varies from pale yellow to brownish yellow. They are found in clusters or groups of 30 or more on the upper surfaces of leaves but scarcely on twigs. They can easily be distinguished from those of *Psylla mali.*

(2) *The Larvae* (Plates XVII, XVIII).

(i) There are five stages, the imago emerging from the fifth (or the nymph). The first four stages correspond closely to those of *Psylla mali* in the external structure, but the fifth instar or the nymph is very characteristic of this insect. It is not uniform in colour but is spotted on the abdomen. The other structures seem to be similar.

(ii) *Secretion.* These larvae exude a waxy secretion which wets the surface of a leaf. There are no white threads as there are in *Psylla mali.* The larvae of *Psylla pyricola* are always wallowing in the secretion. On this honey-dew grows the injurious fungus which has been identified by Massee (of the Royal Botanical Gardens, Kew) as *Cladosporium herbarium.* Thus it will be seen that the habits of these larvae as to secretion are quite different from those of the larvae of *Psylla mali.*

(iii) *Situation.* These larvae are always found on the open surfaces of the leaves of the pear trees. Their responses to surroundings have not been observed.

(iv) *Injurious effects produced by larvae.* These effects are two-fold:

(*a*) Effects due to *Cladosporium herbarium*, the Sooty Mould.

(*b*) Those due to the larvae. The larvae suck the juices of the leaves and thus starve them. The leaf becomes curled and withered and afterwards dries up. When the leaves die the metabolism of the whole plant is interfered with and thus the plant may ultimately be killed.

(3) *The Adult.*

(i) The imago is green when it emerges from the nymph, but it soon becomes dark in colour. The external structures with reference to sex are identical with those of *Psylla mali*.

(ii) *Feeding habits. P. pyricola* do not produce any white spots on the leaves, but on the other hand they produce rather injurious effects. The adult insects secrete honey-dew and wet the surfaces of the leaves, on which grows the same injurious fungus.

Thus *P. pyricola* is injurious in both its stages, *i.e.* in the larval as well as in the adult forms; while *P. mali* is harmful only in the larval form.

(iii) *Reproduction. P. pyricola* is tri-voltine; while *P. mali* is uni-voltine, *i.e.* the former has three generations while the latter has only one.

The following are the probable dates of the three generations of *P. pyricola*:

1st generation ..	.. April and May.
2nd ,, ..	.. June, July.
3rd ,, ..	.. August, September.

P. mali has only one generation from March to September. *P. pyricola* hibernates in the imago stage. The adults of the third generation pass through the winter and lay eggs in the following spring when the females are fertilised. *P. mali* hibernates in the egg-stage; the eggs are laid in September and the larvae hatch out from them in the following spring. In short, *P. pyricola*, when compared with *P. mali*, seems to be as dangerous to pear trees. This pest is gradually spreading, though at present it is only known locally. America and the Continent suffer from this pest. It requires more working out. I have given its description as a contrast to *P. mali*.

X. *Insecticide Treatment.*

In the course of the investigation of the life-history of *Psylla mali* it was found that the larvae are covered with waxy secretion. As they secrete the waxy stuff the under surfaces of the leaves get soiled by the wax and become impervious to water. The buds besides having a waxy covering have also got minute hairs and other structures of their own which make it more difficult for water to reach them. My task was to find a fluid which would thoroughly saturate the bud leaves and so reach the larvae. I have used different percentages of the soap (soft) solution and found one per cent. of the soap solution satisfactory. One per cent. means ten pounds of soap in 100 gallons of water. But the soap solution by itself was not effective enough the kill the larvae. It was tried on some apple trees with the result that 72 per cent. were killed and the rest were healthy enough. The soap solution not only saturates the bud leaves but it engulfs the larvae also, though in some cases without killing them. The reason why 28 per cent. were living seems to be that the soap solution is very effective if it dries instantaneously. By doing so it blocks the respiratory pores (stigmata) of the insects, which are thus suffocated and killed. This means that the soap solution will be more effective on leaves exposed to the wind and the sun. But in the case of buds the leaves are not so exposed and larvae in these buds do not run such risks as those on the open leaves. The soap solution is not poisonous by itself, and if it does not dry up immediately it is utterly ineffective, for the larvae can be happy in it and crawl out of it before it dries up and their stigmata closed up once for all. This would explain why such a large percentage was living with the soap solution. As the soap solution was deficient by itself, I had to seek some poisonous stuff which would facilitate the action of the soap solution. The stuff had to be one of the wax solvents, and for this purpose I used many things:

(1) Petrol.
(2) Kerosene.
(3) Xylol.
(4) Acetone.
(5) Creosote.

All these are more or less wax solvents. The last reagent proved to be the best on trial and I have made use of it. These reagents do not increase the surface tension lowered by the soap solution and they are miscible with it. It must be remembered, however, that though they are poisonous to the insects and wax solvents, they do a great deal

of damage to plants if used in excess. Before I begin the description of my experiments with regard to different insecticides, it would be correct to state the particular times for spraying apple trees for apple sucker. I was very late last year owing to many difficulties. The proper time for spraying is before the floral buds have opened. The eggs begin to hatch as soon as the foliage buds open and there is a great interval before floral buds blossom. If put off too long the spraying will shake the pollen from the flowers and the ovaries will remain infertile. In no case should there be any spraying when the blossom has opened. The setting season begins and the petals begin to drop off and the fruit become set. Then there is another chance of spraying the stragglers—the nymphs which may have been unfortunate enough in the previous larval stages. This final spraying combined with the previous one will completely exterminate the apple sucker from the orchard.

It is a curious fact that spraying at different times in the day has varying results. The same mixture was sprayed over the apple trees at different times:

	Spraying time		Result
25. 5. 13	12 noon.	It was light and windy and hot.	All died instantaneously.
	5.30 p.m.	It was cool.	All died eventually, but at the time of examination 10 or 11 were still struggling for existence.

These variations can be explained. On a bright, hot, windy day the soap solution dries up immediately and the creosote acts very effectively; while, when it is cool, the insecticide does not dry immediately, and creosote seems to be very slow in its action.

These experiments will at least show that the different times of the same day have different effects, though the insecticide may be the same.

Different washes used.

(1) *Rosin Wash.*

(*a*) *Composition:*

Rosin	2 lbs.
Washing soda	2 lbs.
Water	20 gallons.

(*b*) *Action.* As the stuff gets dried, rosin is deposited on the surfaces of the insects and blocks the air holes, the stigmata; the insects are suffocated and thus killed.

(*c*) *Effects :*

(1) It has not penetrated the buds at all.

(2) None of the larvae were touched by it.

(2) *Paraffin Emulsion.*

(*a*) *Composition :*

Paraffin	2 gallons.
Bar soap	$\frac{1}{2}$ lb.
Water	1 gallon.

Diluted 1 gallon to 9 gallons water.

(*b*) *Action.* The fluid is sprayed into minute droplets spread over the surfaces of the leaves—each droplet consisting of two parts—the central core of paraffin surrounded by the outer crust of soapy water. The water then evaporated, and the paraffin core being exposed spread over the surface and the larvae touched by it are killed. The paraffin acts as a contact poison. It has nothing to do with respiration. Thus its action is quite different from that of rosin wash. This is shown by the fact that the larvae do not die as long as there is water, but they do so when the water evaporates and the paraffin spreads.

(*c*) *Effects :*

(1) If used in excess it burns the plants, especially on a bright sunny day.

(2) More than 50 per cent. of the nymphs were killed.

(3) It did not wet evenly. Some drops were resting on the hairs of the bud leaves.

(4) Nymphs were not wetted on the lower surfaces of the leaves.

(3) *Soap-Creosote Emulsion.*

(*a*) *Composition :*

100 gallons of water.
10 lbs. of (soft) soap.
Quart creosote oil (crude, commercial).

I found this emulsion the best of all. Not only is it simple and effective, as it will be presently seen, but it is the cheapest thing on the market. One hundred gallons of the wash only cost 2*s.* 6*d.*, and this price compares favourably with any insecticide available.

I started first of all with the soap solution only, but the results, though not poor, were not very satisfactory. I have already explained why the soap solution by itself is not effective. There is another possibility that the larvae recover the next day. They can withstand suffocation for many hours, and the soap, unlike rosin, does not

completely block the stigmata, rosin being a solid thing. The soap solution has two defects:

(1) It is of use only in case of buds where the leaves are not exposed to the wind and the sun.

(2) The larvae may and generally do recover from the effects of a soap solution after some hours.

The results of the soap solution were (the solution being 1 %):

72 % dead. 28 % living.

In order to remove these two defects the creosote oil was emulsified with it—the oil being poisonous to the insects. These several experiments were tried with differing percentages of the oil, that of the soap (solution) being constant.

(1) With 1-10 or ·1 % of creosote.

22500 cc. water
8 oz. soap — Spraying 2.30 p.m., 24. 5. 13.
$22\frac{1}{2}$ cc. creosote oil

The result being:

39 living
74 dead
106 dead
54 living

Nearly 50 % dead.

(2) With ·2 % of creosote.

4 oz. soap
11200 cc. water — Sprayed at 12.30 p.m.
22 cc. creosote

110 dead
8 living

Nearly 93 % dead.

(They were dead next day.)

(3) With ·25 % of creosote.

4 oz. soap
11200 cc. water
28 cc. creosote

There were three trials. Every time the result was that all the larvae were killed by the time of the examination.

(*a*) *The method of the examination.* The observers (Prof. Lefroy, Mr Davidson, Mr Miles and myself) used to wheel the machine to the apple trees. One of the heavily infected apple trees was selected and was sprayed with the driving jet. Each of us then broke the twigs at random and collected them together. Those twigs were brought home and spread in an open space on papers. When they were fully dry Prof. Lefroy picked out the dead and the living larvae, and thus the different results and the percentages were obtained.

The creosote oil is very harmful to plants and especially to tender leaves. It was tested in those percentages used in the experiments

on different apple trees by Prof. Lefroy, who examined those trees next day and found that no harm was done to them. It seems therefore that the creosote oil in the percentage used (·25 per cent.) is not all harmful to the trees.

(*b*) *Its action.* The action of this emulsion is two-fold and therefore very effective. As it is shown above, the soap solution by itself kills 72 per cent. of the larvae. Its action is also explained. The soap solution, by being mixed with the creosote oil, becomes a deadly poison. The soap solution enters the tracheae and blocks the stigmata and thus introduces the creosote poison into the body. It acts both internally and externally, and thus it becomes very effective. There is no chance of recovery for the larvae, as is the case with the soap solution. The percentage of the creosote, however, seems to be fixed—·25 per cent. being the optimum. Below and above it the results are not very satisfactory.

(*c*) *Effects.* They have been already dealt with. The death roll by this emulsion is very great.

XI. *Enemies of the Apple Sucker.*

As far as I have observed there are no enemies. I have not been able to see any parasite, internal or external, preying on it. The larvae are healthy and normal, and I have not seen any malformation owing to its being parasitised. So it is impossible to say whether there is any parasite controlling the growth and spreading of this pest.

Occasionally I have seen mites attacking the nymphs and adults. The mites are red and large—like those which generally attack aphides (aphis). Besides these mites I have not seen any enemy to the apple sucker.

XII. *Immunity of the Apple Trees to the attack of the Apple Sucker.*

There seems to be no reason why there should be immunity to the attack. Immunity may be acquired or inherent. The apple suckers in the adult stages do not make any damage, and therefore there is no pathological response. The inherent immunity may be due to the fact that the juices of certain apple trees may be distasteful to the apple suckers, while those of the others are sought after with avidity. It must be remembered that the real damage is done by the larvae and not by the adults. The larvae suck the juices of the buds and not the fruits. It seems from what I have observed that there is no

difference in the quality of the juices of the different varieties of the apple trees—they seem to be the same, whether sweet or sour, and they are not disliked by any batch of the larvae.

No doubt there are different trees which are less heavily infected than others, and there are some which are not infected at all. I doubt whether the latter form the case of the immunity. The same variety passes through all stages of infection—some with no larvae, while others are heavily infected with them. It seems to be the case of the chance distribution of the eggs of the apple sucker on different plants.

I have noted down the results of my experiment with regard to the immunity:

	Name of the variety	Sweet or sour	Infection
(1)	Duchess favourite	very sweet	none
	,, ,,	,, ,,	fair
	,, ,,	,, ,,	median
	,, ,,	,, ,,	heavy
(2)	Yellow injesting	sweet	fair
(3)	Warner's king	sour	none
(4)	Stirling Castle	,,	median
	,, ,,	,,	fair
	,, ,,	,,	,,
(5)	Early Julian	,,	medium
	,, ,,	,,	fair
(6)	Worcester pearmain	sweet	none

INSECTICIDES FROM A CHEMICAL STANDPOINT.

By W. F. COOPER, B.A. (Cantab.), F.C.S.,
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As the title implies, this paper puts forward some ideas which, to us, appear to lead to a wider range of choice in insecticidal substances, and to possible improvements in their methods of application.

We are chemists and make no claim to a special knowledge of entomology; yet we have been concerned for some time with the practical control of various horticultural pests and animal parasites, and we venture to hope that the experience thus acquired may be of some little value to the economic entomologist.

On glancing down a list of the substances most generally used in the preparation of insecticides, a chemist is at once struck by the surprisingly small number of compounds which have been employed. It would seem that until recently the changes have been rung on little more than half-a-dozen materials: Bordeaux mixture—lime-and-sulphur—quassia—arsenic—pyrethrum—paraffin, and so on. So-called improvements, which are claimed from time to time, appear as a rule to be confined to some slight modification of one or other of the existing formulae, the number of which is already legion.

In the past the attempts to control entomological pests have been of too empirical a nature. Substances have been tried with little, if any, regard to their precise mode of action, and when a moderately satisfactory material has been found the experimenter has rested content, where he might with profit have continued his enquiries along those lines which this result should suggest. Empiricism generally tends to stifle true research, and genuine progress rarely follows in its train, while patient research on well-organised and systematic lines almost inevitably paves the way to final success.

It is not sufficient to discover that a certain compound is more or less effective for the destruction of specific pests—the further step must

be taken, of ascertaining what particular characteristic of that compound is primarily responsible for the results obtained. For example, in the absence of proof to the contrary, it is not wise to assume that, because tar substances possess insecticidal properties, the latter are wholly dependent upon the presence of phenolic compounds. In the case of coal-tar disinfectants it was the practice until recent times to determine the germicidal value by a chemical estimation of the phenolic content alone, whilst no account was taken of the non-phenolic constituents. It has since been shown, by actual tests on living cultures of bacteria, that some of the non-phenolic constituents may possess an even higher germicidal value than the phenols themselves, and, in consequence, germicidal values of coal-tar disinfectants, based on chemical determinations, have fallen into disrepute. This would have been avoided had a careful examination of the factors which influence the germicidal action of a coal-tar disinfectant been made.

It follows, therefore, that until many, if not all, of the factors which determine the efficiency of an insecticide are known, the observer is liable to draw similarly erroneous conclusions.

Hitherto the economic entomologist in his search for suitable insecticides has confined himself to those compounds which to him appeared to be cheap and easily obtained, but it seems to us that a wide field still remains unexploited, in which, nevertheless, these essential conditions obtain.

There are many organic compounds of probably high insecticidal value, which are readily prepared in the laboratory, and which, if a suitable demand arose, would be commercially possible. The choice of these for experimental trials should not be made in a haphazard manner, but should be preceded by a systematic investigation, so arranged as to determine what particular characteristic conferred the insecticidal property. Two illustrations will suffice to make our meaning clear.

It has been found that xylene is the most effective of the tar hydrocarbons in destroying wood-boring beetles. To what particular property is this superiority due? Does some special grouping of the atoms in the molecule play a part, or is it a purely physical question? If it is a special grouping of the atoms which endows xylene with such a degree of insecticidal efficiency, then it is reasonable to suppose that other compounds with a similar molecular constitution would be equally effective. If, on the other hand, the insecticidal characters of xylene are dependent on its physical properties, then other fluids with identical

physical constants should behave in a similar manner. Unfortunately there is no reliable information at hand to decide the point, invaluable as such knowledge would be as a basis for research on these lines.

Again, the efficiency of carbolic and cresylic acids as insecticides is universally known, and it is reasonable to presume that these compounds possess insecticidal properties by virtue of their phenolic groups. Benzene compounds containing a nitro-group have germicidal properties, and have been suggested as insecticides—as for example, nitro-benzene. It is conceivable, therefore, that the nitro-group, like the phenolic group, may confer insecticidal properties, if introduced into a molecule. Would the insecticidal properties of carbolic or cresylic acid, therefore, be increased by the introduction of one or more nitro-groups? This was the question which the Bayer Farbenfabrik asked themselves as early as 1892, and, as the result of systematic research, they were able to answer it in the affirmative and produce a most valuable insecticide, "Antinonnin." This is ortho-cresol into which two nitro-groups have been introduced, the potassium salt of the resulting compound, owing to its greater solubility, being employed in practice. It is non-corrosive, and attacks neither metals nor textile fabrics. Antinonnin has been extensively and successfully applied in the destruction of the "Nonnen" (*Monacha*) larvae, infesting the forests of Bavaria and Würtemberg; and has also been largely used as a substitute for creosote in the preservation of timber. This affords an excellent illustration of the value of systematic research as opposed to empirical methods.

The subject of insecticidal effect of the introduction of various atomic groups into the molecule needs to be worked out systematically, much in the same manner as that in which Ehrlich carried out his classic investigations on the effect of various organic arsenic compounds on blood parasites. Ehrlich found that the position of the arsenic in the molecule had an enormous influence on the toxic effect of the compound, both on the host and the blood parasite; and, as a result of a long and systematic research, he at length evolved his famous "606," efficacious doses of which, whilst highly toxic to blood parasites, are practically innocuous to the host.

Speaking generally, metals in organic combinations, as distinct from inorganic, are considerably less toxic towards the higher animals and plants, whilst they retain their poisonous action on the lower organisms. This fact suggests the possibility of the use of organo-metallic compounds as insecticides. The insecticidal properties of the metal might

be thereby retained, whilst the injurious effect on the host might be diminished. We are not aware that any organic arsenic compound has been employed in this connection, the principal reason being, possibly, that such compounds are usually too expensive for the purpose; but the use of an interesting organic compound of copper has been suggested. This is cupric-di-methanal-di-sulphite ($Cu(H_2C.OH.SO_3)_2$), which is easily prepared by passing sulphur di-oxide into a suspension of copper hydroxide in 40 % formalin. A clear blue solution, containing 3 % of copper is thus obtained, which, it is claimed, combines in itself a copper insecticide and a sulphuring agent.

The high insecticidal value of emulsions of paraffin or other oils has long been recognised, whilst copper, in one form or another, is in very general use as an insecticide and fungicide. Is it possible to combine the advantages of both? Copper resinate is soluble in mineral oils, so that by emulsifying such a solution of copper resinate, a preparation would be obtained, which might possess the insecticidal properties of both an oil emulsion and of copper.

According to Pickering, the action of Bordeaux Mixture is due to the gradual liberation, by the atmospheric carbon-dioxide, of small quantities of soluble copper sulphate. It is a well-known fact that certain substances are much more reactive when freshly liberated from their compounds. In many cases this is due to their "nascent state"; in others, the extremely fine state of division, in which they are deposited, is doubtless responsible for their increased activity. Atmospheric carbon dioxide might be employed with the greatest advantage in the precipitation of insecticidal compounds in this super-active form, but, with the exception of Bordeaux Mixture, and possibly potassium sulphide, little, if any, use of it has been made up to the present. Let us consider, for example, β-naphthol. This is a constituent of coal-tar; it has high bactericidal properties, and, being a phenol, presumably would act as an insecticide. It is a simple matter to prepare a solution of β-naphthol in caustic soda, so adjusted that a mere trace of carbon dioxide would precipitate a minute quantity of the β-naphthol. Such a solution used as a tree spray might prove to be of the greatest value, because its active constituent would be liberated gradually, and so could only act upon the foliage in extremely minute quantities.

To take another example: preparations containing potassium sulphide (liver of sulphur) are largely used as insecticides. To what particular property these owe their insecticidal action is apparently doubtful. The gradual precipitation of sulphur from the admixed

poly-sulphides is probably largely responsible. But the necessary quantity of carbon-dioxide to effect the precipitation of sulphur from commercial potassium sulphide is very large; consequently the process is slow, and probably some weeks elapse before the beneficial effects of precipitated sulphur come into play. It is, however, not a difficult matter to prepare solutions from which sulphur can be precipitated in an exceedingly finely divided state by a mere trace of carbon-dioxide, and there is little doubt that these would be found more effective than ordinary sulphide preparations.

The efficiency of many insecticides is entirely dependent on the fact that they suffocate the insect by blocking up its breathing orifices. Of this type, viscose suggests itself to the chemist as a most excellent material. Viscose is a derivative of cellulose, which is extensively employed in the manufacture of artificial silk. It is characterised by the fact that even in dilute aqueous solution it forms an extremely viscous liquid, which by exposure in thin layers gives a tenacious and impermeable film. Obviously, viscose preparations could not be used for spraying the entire foliage of trees, but as a winter wash or as a local application, in the case of scale, such are certainly worthy of trial.

So much then for the directions in which a search for new and improved insecticides might be made. Many more could doubtless be suggested, but the foregoing will suffice to indicate the wide field awaiting inquiry.

Quite apart from the quest for new substances, there is another point, which we take this opportunity of emphasizing, because it is one which many economic biologists are apt to lose sight of, in the selection of remedies for the eradication of insect and fungoid pests. This is the extraordinary importance of the *physical condition* of the insecticide in its influence on the efficiency. Attention has already been drawn to the fact that a chemical assay of a carbolic disinfectant is really no measure of its bactericidal power, because it is based on the false assumption that only phenolic compounds have bactericidal properties. But the chemical assay of a disinfectant fails for another reason, and that is because it takes no account of the *physical condition* of the active compounds. It has long been known that, of two preparations containing equal percentages of the same tar acid, *emulsified* in the one case, and in a state of *simple solution* in the other, the *emulsified* preparation possesses a much higher bactericidal power than that containing the tar acid in *solution*. Chick and Martin (*Journ. of Hygiene*,

viii, 5, pp. 698–703) have shown this to be due to the fact that the bacteria are adsorbed on to the fine emulsified particles of the tar acid and are thus brought into direct contact with the germicidal agent in a highly concentrated form. Now, whatever may be the cause, there is little doubt that, of liquid insecticides, an emulsified one is far more efficient than a non-emulsified one. Whether Chick and Martin's explanation holds good in this case also, is questionable; possibly, with very minute insects, adsorption may play some little part. Where, however, an emulsified insecticide is undoubtedly vastly superior to a non-emulsified one is in its wetting-power, and with insecticides this is a point of paramount importance. It is needless, here, to point out the extreme difficulty of wetting the chitinous integument of an insect, or the protective woolly secretion of the aphis of American blight; nor is it necessary to dwell upon the fact that an insecticide cannot do its work unless it actually comes in contact with the insect: such are self-evident to all who have to deal with entomological pests. Perhaps what is not so generally recognised is the fact that different liquids have very different wetting powers. A simple experiment serves to illustrate this. The American cloth back of an exercise book may represent, sufficiently well for the purpose, the chitinous integument of many insects. When water is poured on to the back of such a book it runs into droplets and flows off without wetting it, precisely as water would run off the integument of the insect. If, however, an *emulsion* is poured on to the book, the whole surface is completely wetted, and the liquid forms a continuous film. If, now, the emulsion is washed off by a stream of water, the unwettable character of the surface again becomes evident, the water flowing into droplets and running off. A liquid insecticide, in order to be efficient, must be capable of thoroughly wetting the insect and its surroundings. It must "*run*" easily and be able to penetrate the interstices of the buds, the folds and crinkles of the leaves, waxy secretions, hairy or woolly surfaces, the minute orifices of the insects themselves, etc.; and experience has shown that liquids of low surface tension, *e.g.* emulsions, are best suited to this end.

There is an additional advantage in the use of an emulsion, which was brought out in a pertinent manner in some work carried out by one of us (W. F. C.) in South Africa four or five years ago. We were then concerned with the eradication of the Bont Tick, which infests cattle and transmits the fatal disease—*heart-water*. Sodium arsenite had long been used as a means of destroying these ticks, but it was found that, at the strength necessary to kill the ticks, the cattle themselves were

frequently so badly scalded that death ensued. By employing an emulsified oil in conjunction with the sodium arsenite and so ensuring complete wetting of the hide, Cooper found that a much lower percentage of arsenite was sufficient to destroy the ticks and that the risk of scalding was practically removed. The scorching of sprayed trees is not an uncommon occurrence, and it is most probable that the means adopted for the prevention of the scalding of animals would also prove effective in preventing injury to foliage.

With solid insecticides or fungicides, such as copper carbonate, lead chromate, lead arsenate, etc., which are usually applied, as aqueous suspensions, in the form of a spray, the physical condition of the solid plays a by no means unimportant part in the efficiency of the preparation. According to the manner of precipitation, these compounds may be obtained in either a coarse granular state, or as a fine light flocculent precipitate. In the first case, the suspension settles rapidly and requires constant attention in the matter of stirring; further, it is liable to clog the nozzles of the spray-pump and, in addition, after drying, is apt to fall from the sprayed leaves. On the other hand, a fine, flocculent precipitate has none of these disadvantages.

These examples will serve to show how very greatly the efficiency of an insecticide or fungicide is dependent upon conditions other than chemical; they indicate that, as with disinfectants, a chemical assay alone must give a wrong impression of the actual value; and these are facts which must not be lost sight of in the consideration of the standardisation of insecticides.

As a matter of fact, we are only just entering upon the scientific study of the preparation and application of insecticides. That our methods have been too empirical in the past is largely due to the lack of co-operation between the economic entomologist and the chemist; neither can hope to achieve real success alone. It is for the entomologist to investigate the various pests, their life history, habits and vulnerability; it is for the chemist to devise and elaborate means of attack, based upon the information supplied by the entomologist and upon the chemical and physical properties of the substances with which he has to deal.

INSECTICIDES.

By H. M. LEFROY.

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It would be interesting to collect information as to the insecticides in general use in horticulture in different countries in any one season and to determine as far as possible what were the circumstances leading to their use. There is, I believe, a fashion in insecticides: at one time Paris Green and London Purple ruled; then came Lead Arseniate in America; this is apparently giving place to Zinc Arseniate and Barium Arseniate, while there is reason to hope that Lead Arseniate, and perhaps Lead Chromate, will be more familiar in this country.

So, too, for contact poisons. I remember the era in America of paraffin emulsions and rosin washes; then came whale oil soap; lime salt and sulphur followed, then the heavy oils and then "miscible oils." The vogue of the lysol and similar mixtures on the Continent has to be noted, and we may note that miscible oils are being used more freely in Australia and South Africa.

In estimating the causes of these successive fashions one would need to distinguish the effect of the recommendations of State Departments of Entomology and the influence, increasing in recent years, of the weight of pure advertising by firms interested in the sale of the particular products they were able to handle. In this paper I omit entirely the "patent" or "proprietary" insecticides in so large use, since it is not always clear on what ingredients their action depends, and I confine myself to insecticides of definite known constitution, or those which depend upon the presence of some known chemical compound.

It is not easy to ascertain exactly what insecticides are at present used on a large scale in this country, but I have tried to do so from three sources: the first is the published recommendations of horticultural journals; the second is the recommendations in the leaflets of the Board of Agriculture; the third is those that I gather from general

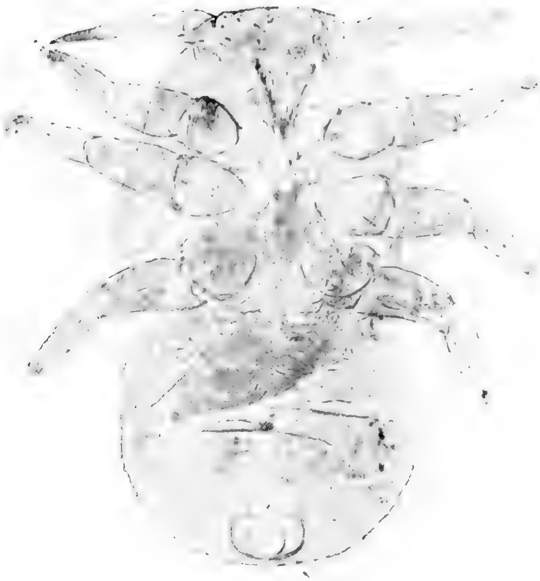
information, observation, reports, papers in actual use. For the first I attach extracts from 16 consecutively weekly issues of the *Gardeners' Chronicle* in 1913, these occurring in the contributions of head gardeners or in editorial advice. I think they reflect accurately current ideas and practice.

Hardy Fruit Garden .. For aphides	The tree syringed with a very mild insecticide. In some cases it will be found necessary to use tobacco powder, which should be left on for two or three days, and then thoroughly syringed off with clear soft water. p. 268, 26. 4. 13.
Abies diseased .. .. Aphis. Editorial	Spray three times at intervals of four days, with a solution of soft soap and quassia chips, and repeat the spraying in September. p. 279, 26. 4. 13.
Broad beans .. .. Black fly	Syringe the plants frequently with a fairly strong solution of soft soap. p. 280, 26. 4. 13.
Cool orchard house ..	The eradication of insect pests can be done either by fumigation with nicotine, or by spraying with some good insecticide. p. 288, 3. 5. 13.
Market Fruit Garden .. Insect pests	For some unknown reason, insect pests are troubling me at present much less than usually. It is many years since I found so few Apple suckers. Most varieties of Apples in my orchards are almost free from this enemy, and many are nearly exempt from the attacks of aphides and caterpillars. It would be interesting to learn whether this comparative immunity is general or not. If it is not so, perhaps persistence in destroying the pests for years past is meeting with a fitting reward. But it may be that suckers and aphides hatched prematurely during the mild winter or in March were killed by frost. Or, again, spraying with a strong solution of lime-sulphur just before the buds burst may have done something in coating over eggs or destroying mother queen aphides. It is too early, however, to assume that the comparative immunity will continue. There can hardly be a bad attack of the sucker after this; but the aphis and the caterpillar have plenty of time during which to appear in strong force. Already the hope that Plums would escape the usual infestation of aphis has been disappointed. On April 24 no attack could be observed on any but two varieties; but on the 29th there were aphides on all. As the leaves are curled over the pest, spraying would be a mere waste of time and money.
The first summer spraying	Owing to the partial immunity of Apples from insect pests, the usual spraying before the expansion of

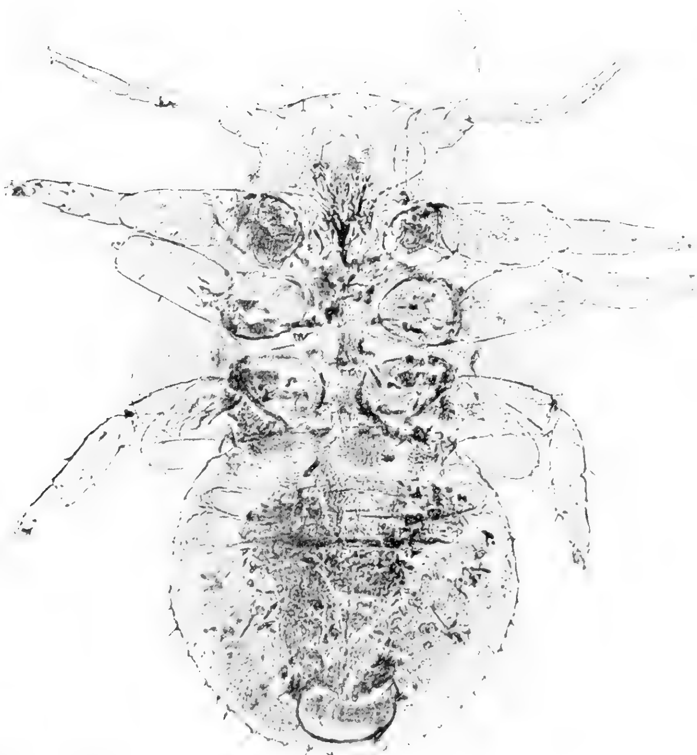
blossom was to a great extent dispensed with, only varieties which were badly attacked by aphis, sucker, or caterpillar, or all three pests being sprayed. This was a great relief, and it is not by any means certain that it might not have been extended to all varieties without any bad results. For on every occasion rain fell a few hours after the spraying was done, probably washing most of the spray fluid off the trees, and off the insects that had been wetted by it. There was no question of waiting for settled fine weather, as the work had to be done before the expansion of the blossom. Arsenate of lead was combined with the soft-soap wash for aphis and sucker, in order to poison the food of caterpillars. If pests should attack the varieties not sprayed, they will be treated after the fall of the blossom, and in any case varieties subject to scab will be sprayed with lime-sulphur of summer strength.

Results of spraying

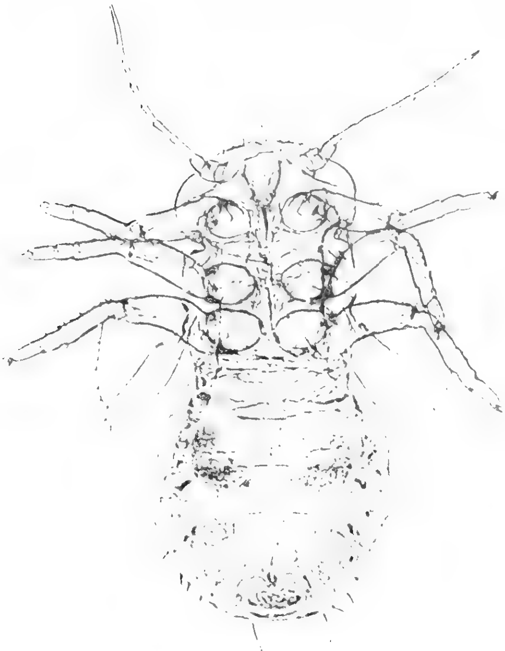
One of the most unsatisfactory features of spraying is the difficulty of determining its results, and that difficulty has proved particularly great this season. Even in the cases of Apples most infested, such as those in which five or six out of twenty trusses of blossom were found to contain aphides, and three or four a few suckers, I could not find more than one dead aphis or sucker in fifty trusses examined a day or two days after the spraying. I found more live ones, but very few even of these. The question, then, is whether the pests, killed or weakened by the wash, were washed out of the trusses by heavy rain. It is commonly assumed that aphides are washed off the trees by rain, and particularly by a thunderstorm; but, so far as I know, this is an assumption which has never been actually proved. Some trusses found to be infested by aphides could be labelled, some of them being sprayed and others not sprayed, care being taken to avoid any more thorough spraying than would be given on a large scale. If the insects could be counted beforehand, so much the better. Examination could be made 24 hours after the spraying, results being noted; and again after the next fall of rain, if it occurred soon enough. Rain might hold off too long, and the experiment would then have to be repeated. In noting the results after rain, if any pests were found to have been washed off the trees, it should be noticed whether more were ousted from the sprayed trees than from the others. As to a thunderstorm, there can hardly be any special



Apple Sucker. 3rd Instar.

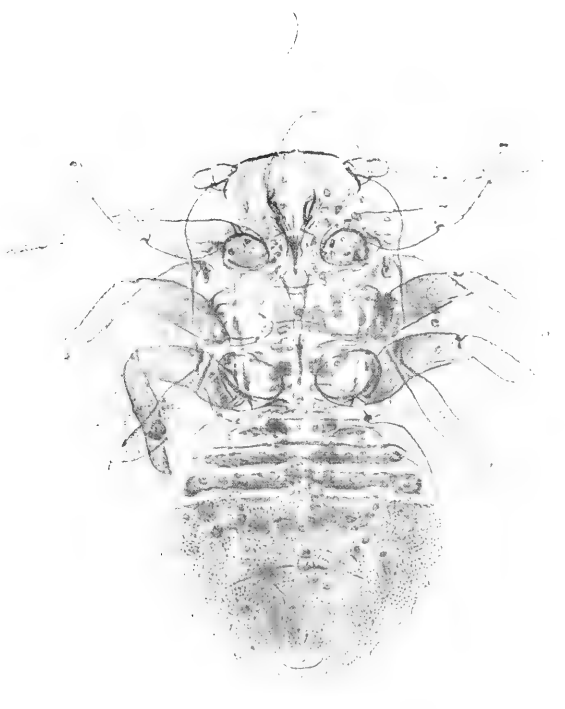


Apple Sucker. 4th Instar.



Apple Sucker. 5th Instar.

Pear Sucker. 4th Instar.



Pear Sucker. 5th Instar

effect from it, unless the rainfall happens to be more violent than in an ordinary storm, as it is not at all likely that a specially electrical condition of the atmosphere affects the aphis. A busy fruitgrower can hardly find time for such experiments as are suggested. They should be carried out by the authorities paid out of public funds to undertake research. As matters stand, I do not know whether the expense incurred in spraying has been useful or almost useless. There is too much reason to fear that the arsenate of lead has been all, or nearly all, washed off the trees by rain, and that the caterpillars will be able to go on feeding with impunity. They, like the other pests, were in the trusses of blossom buds and the surrounding leaves. "A Southern Grower." p. 301, 10. 5. 13.

Roses .. .. .. Aphis	Should the pest appear on the leaves, syringe the trees with a mixture of soft soap and sulphur. The sulphur will also check mildew. Caterpillars are particularly numerous this season and unless they are diligently sought for they may do much damage. p. 308, 10. 5. 13.
Hardy Fruit Garden .. Gooseberry caterpillar	If the pest has already taken a hold on the bushes, they should be syringed at once with a good insecticide. Some mixture containing a certain proportion of nicotine will answer the purpose best, it will kill the grub in a few minutes. The trees should be afterwards syringed with clean, soft water. p. 309, 10. 5. 13.
Editorial .. .. Vine weevils	Place freshly tarred paper under the vines, then approach the vines with a lantern in the hand, giving each rod a slight shaking....It is difficult to kill the larvae in the soil for they seem proof against any but the strongest and most dangerous applications. p. 320, 10. 5. 13.
Fruits under glass .. Red spider	The vines will need syringing occasionally with an insecticide to destroy red spider. p. 326, 17. 5. 13.
Hardy Fruit Garden .. Apricot	A small yellow caterpillar is a great pest: this pest should be hand-picked and destroyed. After a thorough search syringe the trees with a weak solution of nicotine. p. 327, 17. 5. 13.
Market Fruit Garden .. Apple sucker	Our trees were sprayed with Buxton lime and in the case of Warner's King, which I have always found the most susceptible to sucker, I used salt with the lime. The spraying was done just before the flower buds parted from the cluster ready for expansion. p. 332, 17. 5. 13.
Editorial .. .. Apple blossom Bud moth	The trees should have been sprayed with arsenate of lead...as soon as the petals have fallen, spray with 1 lb. of arsenate of lead paste to 25 gallons of water. As

	there are some aphides in the trusses add 2 lb. of soft soap to the 25 gallons of wash. p. 336, 17. 5. 13.
Editorial .. .. Spruce fir 'Spruce gall'	Spray in winter with a wash of 3 lbs. soft soap, 5 gallons water, and 1 pint of paraffin thoroughly mixed. p. 336, 17. 5. 13.
Hardy Fruit Garden .. Pear trees on walls	Black and green aphides will soon make an appearance on the ends of the shoots and should be destroyed by syringing with insecticide. Leaves that are infested with caterpillars or (? of) the Pear moth, should be gathered and burned. p. 367, 31. 5. 13.
Editorial .. .. Aphis and red spider on vines	To destroy aphis, it is best to fumigate with a nicotine preparation. For red spider, the leaves may be sponged with a little soapy water—half an ounce of soft soap to one gallon of water—mixed with half a pound of flowers of sulphur and kept stirred. Or flowers of sulphur may be applied dry with the Malbec bellows. p. 375, 31. 5. 13.
Roses .. .. .. The flower garden	Syringe roses with an insecticide at least once a week to keep aphis in check. p. 383, 7. 6. 13.
Fruits under glass .. Red spider	The trees should be syringed frequently with an insecticide. p. 383, 7. 6. 13.
Public parks and gardens Tree pests in London	The Goat moth (*Cossus ligniperda*) is far more common over the London area than is generally supposed, and this may also be said of the Wood Leopard moth (*Zeuzera æsculi*), both of which attack the Elm, Poplar, Ash and Oak. The larvae of both moths, which are deposited on the bark of the tree in July or August, tunnel into the wood and do much damage to the timber as well as the health of the tree. Placing cyanide of potassium in the hole and closing the aperture is the best method of destroying the caterpillar, though we have used gas tar in a similar way with good results. Dislodging the caterpillar by means of a bent wire has been successfully carried out. Lime trees all over London are attacked by the caterpillar of the Lime Looper moth (*Hybernia defolaria*), while the Thorn fly, an Aphis, attacks whole hedges of the Hawthorn as well as specimens standing singly. Sponging with tobacco water is to be recommended for the latter, and for the Lime trees caterpillar bands of any sticky substance painted around the stems will prevent the insects ascending to the branches. Red spider (*Tetranychus telarius*) is another formidable insect pest that not infrequently attacks the leaves of several species of hardwooded trees, and is often the cause of death of the Ivy, particularly when grown as a ground carpet. The leaves turn a rusty-brown colour, crumple

up, and finally fall off, the whole plant dying in consequence. Large areas of the Ivy used for ground work in various parks and gardens of London have been killed outright of late years. Spraying with soft soap will prevent the insect from spreading. Though the Beech is by no means a common tree in London, yet of the few specimens to be found, many are attacked by *Cryptococcus fagi*, which is alarmingly on the increase in this country. Paraffin or petroleum emulsion will destroy the insect, and scrubbing the bark with a rough brush and soft soap is an excellent remedy. Wholesale destruction to the leaves of the Spindle tree and other species of Euonymus is yearly occasioned in some of the London parks by the caterpillar of the small Ermine moth, myriads of the caterpillars appearing on the foliage during summer. So rapidly does this insect increase, and so verocious is its appetite, that a shrub will be completely stripped of its foliage in two or three days. Spraying with XL All Insecticide or petroleum emulsion is the best remedy. Where Oak trees are found in London, the Oak-leaf Roller moth (*Tortrix viridana*) is usually present about the beginning of June. It is a very destructive insect, and attacks not only the leaves, but buds and inflorescences, and usually works from the top of the tree downwards. Where only a single or few Oaks are attacked spraying may be resorted to, but hardly any remedial measure can be adopted in a clump or plantation of the tree. Starlings, rooks and other birds destroy vast numbers of this pest, and should be encouraged. By "Superintendent." pp. 400, 401, 14. 6. 13.

Apples and plums .. Spraying lime-wash just before the buds approach the bursting stage in dry weather.

An important object lesson

Very striking evidence as to the advantage of spraying Apples and Plums with lime-wash, as thick as it can be got through the spraying machines, was obtained in Mr Hooper's orchards. In one portion of the farm all the Apple and Plum trees had been sprayed with this wash, nothing being added to the lime, except water, while they were left unsprayed in the rest of it. The lime-sprayed Apples and Plums were free from the aphis blight, while those not sprayed were very badly infested. If memory serves, the contrast applies also to Apple sucker infestation. At any rate, a mere glance was sufficient to allow any one to see it in relation to the aphis blight, and growers elsewhere to

whom this striking case was named said that they had seen similar results from lime spraying. Mr Hooper's explanation is that the lime coats over the eggs of the pests, and extracts moisture from them, thus destroying their vitality. Lime-wash must be strained before it is put into a spraying machine, and it is important to do the work only in dry weather, and to cover every twig. If rain occurs before the stuff has dried thoroughly on the trees, the lime is easily washed off; but it sticks on well after being dried. In the case under notice the spraying was done as soon as there was any sign of an attack by birds upon Plum buds. Apart from this attack, however, just before the buds approach the bursting stage is probably the best time to apply the lime-wash. "Southern Grower." p. 414, 21. 6. 13.

Flower Garden. Aphides on chrysanthemums	It is wise to spray with some insecticide of moderate strength. p. 436, 28. 6. 13.
Hardy Fruit Garden .. Wall trees	Red spider, syringe the foliage constantly with water, to which has been added a little quassia extract.
	If the cherries are infested with black fly, the affected shoots should be cut away and the trees syringed with an insecticide. After each application a syringing of clean water should follow. This method will be found to be a great improvement on the old plan of applying tobacco powder. p. 437, 28. 6. 13.
Editorial .. .. Cabbage root maggot	Soft soap, one quart, in one gallon of boiling water. Add one pint crude carbolic acid and dilute with 30 times its bulk of water. Syringe the ground around the attacked plants. p. 444, 28. 6. 13.
The spruce aphis ..	Spraying with paraffin emulsion is recommended. Soft soap and quassia extract may also be tried. p. 5, 5. 7. 13.
Hardy Fruit Garden .. Black aphis	If there are bad infestations the growths most affected should be cut off and burned and the tree syringed afterwards, first with an insecticide, then with clean water. p. 9, 5. 7. 13.
Editorial .. .. Conifer coccus	Next winter drench the trees thoroughly with soft soap and paraffin emulsion. p. 20, 5. 7. 13.
Fruits under glass .. Peaches	The foliage should be syringed thoroughly or washed by means of the garden engine two or three times a week. This will cleanse the leaves of insect pests. p. 29, 12. 7. 13.
Editorial .. .. Celery fly	Pinch the maggots in the leaves and remove the leaves. ...Afterwards you can make the plants distasteful to the flies by syringing them with quassia extract, or you may scatter soot, lime, etc. p. 60, 19. 7. 13.

Editorial .. .. Ripersia on palm roots	Remove the plants and spray the exposed roots and soil with carbon bi-sulphide, using a small glass spraying apparatus. The process must be repeated. Another plan is to have holes in the soil and pour one tea-spoonful of the carbon bi-sulphide in each hole. p. 76, 26. 7. 13.
Editorial. Rose leaves	'Extract of Quassia.' p. 76, 26. 7. 13.

Board of Agriculture Leaflets.

Mangold fly	paraffin	1 gallon	Formula 1.
	soft soap	½ lb.	
	water	10 gallons	
Onion fly	paraffin	3 pints	Formula 2
	soft soap	½ lb.	
	water	7 gallons	
Surface caterpillars	soot and lime		
	Paris green	1 lb.	
	water	50 gallons	
Celery fly	paraffin	1 quart	Formula 3.
	soft soap	½ lb.	
	water	10 gallons	
	carbolic acid	1 pint	
	soft soap	½ lb.	
	water	10 gallons	
Carrot fly	paraffin	2 gallons	Formula 4.
	soft soap	½ lb.	
	water	60 gallons	
Red spider	sulphur		
	paraffin	7 gallons	Formula 5.
	soft soap	6 lbs.	
	liver of sulphur	2½ lbs.	
	water	100 gallons	
	sulphate of iron	8 ozs.	Formula 6.
	caustic lime	4 ozs.	
	paraffin (solar)	16 to 24 ozs.	
	water	10 gallons	
	liver of sulphur mixed with quassia wash		
Asparagus beetle	Paris green	1 lb.	
	water	200 gallons	
	arsenate of lead	3 ozs.	
	treacle	1 lb.	
	water	10 to 12 gallons	
Thrips	pyrethrum	1 oz.	
	soft soap	1 oz.	
	water	2 gallons	
Hop aphis	soft soap	4 to 10 lbs.	
	water	100 gallons	
	or with 6 lbs. quassia chips		

Pest	Ingredient	Quantity	Remarks
Aphides	soft soap	6 to 10 lbs.	
	water	100 gallons	
	or with quassia 6–8 lbs. added		
	paraffin	2 gallons	On dormant trees (Woburn formula).
	soft soap	1½ lbs.	
	caustic soda	6 lbs.	
	water	28 gallons	
Cabbage fly	paraffin	1 cupfull	
	sand	1 pailfull	
Black currant gall mite	lime	1 lb.	
	sulphur	1 lb.	
	water	20 gallons	
Vine weevils	soft soap	1 quart	
	crude carbolic	1 pint	
	water	30 gallons	
Winter moth	Paris green	1 lb.	
	water	200 to 250 gallons	
	arsenate of lead paste	2 lbs.	
	water	50 gallons	
Gooseberry sawfly	hellebore	1 oz.	
	flour	2 ozs.	
	water	3 gallons	
	Paris green paste	½ oz.	
	water	10 gallons	
Apple sucker	paraffin	2 gallons	Formula 7.
	soft soap	½ lb.	
	water	11 gallons	
	carbolic acid	2 to 3 gallons	
	soft soap	6 lbs.	
	water	100 gallons	
Woolly aphis (Winter washes)	caustic soda	10 lbs.	
	carbonate of potash	10 lbs.	
	soft soap	2 or 3 lbs.	
	water	100 gallons	
	soft soap	1½ lbs.	Woburn formula.
	paraffin	2 gallons	
	caustic soda	6 lbs.	
	water	28 gallons	

Speaking generally, the following are methods in fairly general use:

1. Lead arseniate or Paris green for caterpillars.
2. Soft soap and quassia for hop aphis; soft soap alone or with quassia extract for aphides generally.
3. Sulphur in some form for red spider.
4. Washes containing free caustic alkali for cleaning tree trunks in winter.
5. Paraffin in very weak emulsion with soft soap or paraffin stirred up in water for garden pests.

6. Lime, salt and sulphur in vague proportions for apple sucker, etc.
7. Lime washing for winter use.
8. Nicotine as a general panacea for all pests, as a stomach poison for caterpillars, as a contact poison for apple sucker, aphis, etc.

It will be admitted probably that these insecticides have come into use on purely empirical lines; the use of arseniates has probably come from human toxicology, and a very exhaustive inquiry into the action of some mineral compounds in India[1] has not produced anything more poisonous; it is probably a question of the *form* of arsenic to be used. But what has governed the choice of insecticides that do not act on the internal organs, but those acting from without? I think none but tradition and purely empirical practice, with experience in large scale experiments as a deciding factor.

Is experience on a large scale experiment of much real use? It is in some cases, such as mussel scale, where the insect is one-brooded; I doubt if it is much use in a many brooded or migrating insect, such as an aphis. The factors that control the increase of aphis are many and it would require very careful examination of the conditions to say that the spraying had done the real work, or that the actual nature of the insecticide had been the deciding factor. Suppose a grower of plums sprays for the Leaf Curling Aphis in June; a week after he looks for aphis and finds none; he thinks it is the spraying, whereas it is the migration of the aphis from the plums that has produced the absence.

It is worth while thinking for a moment how these insecticides act; what actually happens when paraffin emulsion is applied; where does the paraffin go to, what tissue does it affect, how does it work? A Board of Agriculture Leaflet states "The presence of the soft soap causes the wash to touch the aphis, and as it dries the thin layer of soft soap clogs the breathing pores and kills the insect" (Hop aphis). Did the author of this statement really know this, or was it simply the generally accepted statement? If so, why do most growers add quassia, and why does quassia kill aphis? what does quassia actually do? I do not think actually that anyone can tell us what the quassia extract does, and I believe that we shall get much better insecticides when we know how it is that these things kill. What is it that happens? If we know that, can we not devise insecticides that make this happen, not that happen to kill?

[1] Lefroy and Finlow. Memoirs of the Agricultural Dept., India. *Entomology*, vol. IV. no. 5.

If we did, it is likely that some of them would be much the same as before, since the sum total of human experience, however got, brings one near the truth. Experience tells us that paraffin kills; it does not tell us how; but knowing how is not going to tell us not to use it. Paraffin will still kill; only ultimately out of knowing why, we shall know whether paraffin itself is the best or whether there is something better not yet tried.

In considering the question of insecticides there are a number of points and I would like to suggest two:

1. *Spreading over and wetting the plant.* In many cases it is necessary to spread over or wet the plant in order that the substance contained in suspension or in solution should be spread over the leaf.

If a leaf is sprayed with mercury, the mercury would not spread over or wet it; the mercury would draw into drops and run off.

If it is sprayed with water, the water might spread and it might not 'wet'; on a cabbage leaf it would not spread or wet, on others it might.

If you sprayed it with pure paraffin it would spread over and wet all the plant and the paraffin would 'creep.' Why this difference of behaviour? It is partly due to two things: the surface tension of the liquid, high in mercury, middling in water, low in paraffin; the question of the inter-solubility of the liquid of some constituent of the surface of the leaf, *e.g.* the wax on the cabbage leaf, being totally insoluble in the water and causing the water to roll off at once.

To spread, therefore, one must presumably have a low surface tension, and to wet also have a wax solvent or a liquid that will be absorbed by or dissolve the outer coat. Now leaving the question of a leaf with its broad surface, take the case of a bud or a curled leaf: here still more the surface tension question is apparent as the liquid might need to penetrate the curled leaf and act by capillarity. I will quote a case here I had need to go into carefully: we had a disease on indigo in which the plant curls into a compact knot at the tip; in this lives a *Psylla*. It was a question of finding an insecticide that would wet and penetrate. We found by experiment that some insecticides penetrated better than others. We found that they varied according to the concentration, and we eventually found one that penetrated so well as to go right in.

Dr Leather, the Imperial Agricultural Chemist, very kindly measured surface tensions for me and this last had the lowest. It was an "oleic" acid soap at 1 lb. in 12 gallons of water. It was the

best soap we got and it was better than rosin compound, oil emulsions, soda solutions and other things. An oil emulsion in ·8 per cent. soap solution has a higher tension than the soap solution. We tested 'penetration' by dipping curled heads of the plants, then cutting them open and seeing what had happened.

Now in this case it was purely one of getting a commercial product of low enough surface tension to wet and penetrate the curled plant. We had to think afterwards of what we could put in to kill the insect. A similar case exactly will be described to you in the paper by Mr P. R. Awati.

Apart from the mere surface tension, what of the different behaviour of a liquid on an ordinary leaf or on a cabbage leaf: is there a reaction between the liquid and the surface depending on the latter? I am not a physicist and cannot say, but I believe there is and, so far as I understand it, I explain it below. But you can get round this in some cases by adding to the liquid a solvent of the wax (if any) in the plant. For instance, a cabbage leaf behaves very differently to a liquid containing a solvent of its wax than it does to the liquid without; for the solvent dissolving the wax eliminates the wetting question since the wax is there already, and it becomes therefore a question of 'spreading.' Spreading power, even more than wetting, depends on low surface tension and we may, I think, distinguish "spreading of a liquid over a surface it never wets" and wetting due to the liquid actually entering into solution with a substance on the leaf surface. You may attain 'spreading' of the liquid by either method but not wetting.

I am indebted to Dr Vaughan-Cornish for a reference to Clark-Maxwell's *Theory of Heat*, in which surface tension is discussed. I have endeavoured to extract the gist of the physics of surface tension so far as it refers to this problem.

The spreading power of a liquid on a solid depends in this way on surface tension:

When a solid body (the leaf) is in contact with two fluids (air, wash) then if the tension of the surface separating the solid from the second fluid (wash) exceeds the sum of the tensions of the other two surfaces, the second fluid will gather itself into a drop and the first fluid spread over the surface, *i.e.*

$$\text{If} \quad \text{S.T. of Wash and Solid} > \begin{array}{l}\text{S.T. of Wash and Air}\\ + \text{Air and Solid,}\end{array}$$

then the Wash goes into a drop.

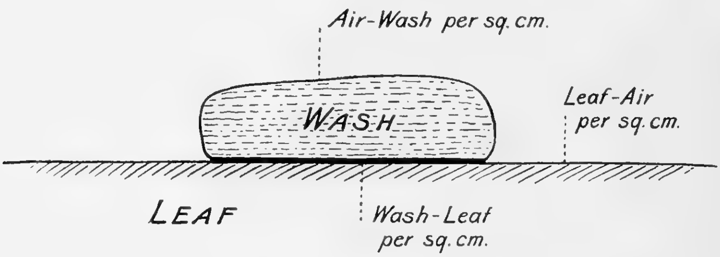
If the reverse, the Wash spreads over the whole surface and will wet the Solid.

Assuming then that the surface tension of the air and the solid (the leaf) is always the same, and that the surface tensions of Wash-Solid and Wash-Air vary proportionately according to the nature of the wash, then clearly the measure of the surface tension of Wash-Air is an indication to us of the wetting power, and the lower this is the greater the chance of wetting.

The equation is

$$\text{Wash-Solid} < \begin{matrix}\text{Wash-Air}\\ + \text{ Air-Solid,}\end{matrix}$$

clearly the lower the two Wash surface tensions, the more likely are we to get the one we want.



The Air and Water surface tensions of these liquids are:

	Air	Water
Water	8·253	—
Petroleum	3·233	2·834
Mercury	55·03	42·58

I have not the surface tensions of any of these with a leaf surface so I cannot work out an equation, but the above figures show why, for instance, mercury and petroleum and water behave differently as regards leaf surfaces.

It will be noticed that it is not only the wash-air surface tension that counts, but the wash-solid and the solid-air. The difference between the wetting power of water on a cabbage and on an apple leaf is due to the difference in surface tension to air and wash between the wax on the cabbage leaf and the substance on the apple leaf. In the first case

$$\text{Wash-Wax} > \begin{matrix}\text{Wash-Air}\\ \text{Wax-Air}\end{matrix}$$

and no wetting occurs by the wash.

In the second case

$$\text{Wash-Apple leaf} \left\langle \begin{array}{l} \text{Wash-Air} \\ \text{Apple leaf-Air} \end{array} \right.$$

and wetting occurs.

Therefore, the nature of the actual substance on the surface of the leaf determines whether the wash will wet or not.

If then we knew the surface tensions of

plant-air,
plant-wash,
wash-air,

we could always tell if the wash would roll off or not. So for the insect: if we knew the surface tension of

aphis-air,
aphis-wash,
wash-air,

we should know if our wash would wet the aphis or not. As we do not know these, and as our plant-air, or aphis-air, remains a constant, we strive to make the wash a practical success by getting one in which wash-air (measurable) and therefore wash-plant is as low as possible. One imagines that, had insecticides received attention from chemists and physicists, the constants surface tension of plant-air, plant-wash, wash-air could be looked up, as also the more complex surface tensions of emulsions. When drops of oil float in an emulsion they affect the surface tension of the emulsion in relation to air and plant.

2. The next point is this: how do these insecticides act; must the liquid spread over the insect, must they 'wet' it, and, if so, then how do they act?

There are, I think, three points:

(1) Mere spreading over mechanically.
(2) Wetting with spreading.
(3) Toxic action after wetting.

(1) In the first case I take such actions as lime wash, which spread over mechanically and never wet; the action may be due to mechanical causes solely, probably suffocation.

(2) Wetting, including spreading, means the insecticide is in physical contact with the body. What does this really mean? Does it mean that the head, the segments, the antennae and legs are wetted, or that only parts are, or that there is a film of the liquid lying over the whole insect but not actually in contact, say, with the under surface?

I take it to mean that the insect is actually in contact with the insecticide all over without any air-film between. It means, for instance, that the liquid is in contact with the spiracles.

(3) Means that *it also has a toxic action.* Now assuming that we have an insecticide that spreads, that wets and that penetrates to the insect, what happens then we do not know.

With a view to getting some accurate ideas I made a large series of experiments with meal-worms with these results:

1. No action is got by applying any liquid for a short time to the skin, but many act at once if applied to a single spiracle.

2. Interference with the mechanical functions of at least five pairs of spiracles is necessary to produce any symptoms due solely to mechanical interference.

3. Closing all spiracles produces a condition we may call 'rigour,' in which a liquid will enter the spiracles.

4. It is impossible to get a liquid to enter one spiracle unless this condition is produced.

5. Dipping a meal-worm in a liquid produces the condition in which the liquid enters. We can therefore compare the effects of liquids by this means.

6. Of liquids tested the following results were got:

Killed all	*Killed some*	*Killed none*
Clove oil	Quinoline	Picric acid in water
Xylol	Carbolic acid	Alcohol 70 %
Turpentine	Formol 4 %	Nicotine 1 % aq.
Nitro-benzene	Pyridine	Acetone
Chloroform	Acetic acid	Ether
Amyl acetate	Eucalyptus oil	Chloral hydrate aq.
Cymene	Methyl salicylate	Water
Pseudocumine	Aniline	
	Acetic ester	

Now results with meal-worms are not of much direct use and we must, for the moment, eliminate the peculiar 'rigour' results. But they show us, I think, that a much greater range of liquids than are generally used have a toxic action and that we must attach far more weight to the details of the structure of the spiracles and tracheal system.

It would look even as if only through the spiracles could one reach most insects with an insecticide, and that the insecticide that did not actually fill the spiracles was not acting. I suggest this is why contact poisons fail against large insects as a general rule; the liquid may wet

but does not wet the whole insect and so the spiracles, or part of them, are free.

The positions of the spiracles, for instance in a Scale Insect, a Psylla, an Aleurodid, and an Aphid, are very different indeed. Their structure is different, they have different arrangements for closing them. In Psylla and Aleurodes the adult is very readily killed with insecticides, partly probably because it has very inefficient spiracles and requires much air, whereas the young form is harder to kill because it has a very efficient closing and protecting apparatus and requires less air.

What I suggest is that the way to tackle the question is first to investigate the tracheal system of the insect. Second, to investigate the wetting action of the insecticide on the plant, unless the insect is fully exposed. Thirdly, to investigate the wetting action on the insect, or the dissolving of its waxes or coating; and fourthly the actual toxic ingredient that would be added to the insecticide to act on the insect when it reached it.

Are any of these factors really taken into account in the recommending of insecticides? I think they should be, and there is here a large field for research.

In preparing this paper I have not attempted in any way to summarise the present practice of insecticides outside this country; this would be a very large subject, complicated by the now enormous use of insecticides sold under fancy names by firms who may or may not have any real knowledge of entomology. But I would like to include abstracts of some papers published in America.

"How contact insecticides kill," G. D. Shafer (*Michigan Sta. Tech. Bul.* XI, pp. 65, pls. 2, figs. 7). This bulletin consists of two parts, the first of which (pp. 8–53) deals with the effects of certain gases and insecticides upon the activity and respiration of insects, and the second (pp. 53–64) with some properties of lime-sulphur wash that make it effective in killing scale insects, especially San Jose scale. Abstracts of these have been previously noted (*E.S.R.*, XXV, p. 665). The investigations conducted and here reported in detail have been summarised by the author in the following general conclusions:

"Usually contact insecticides do not depend upon one property or means alone for their effectiveness, yet as a rule some one property is chiefly concerned. Alkaline washes, corrosive sublimate solution, and other fluids, which are capable either of dissolving or of precipitating certain constituents of insect tissues, are able to penetrate the chitin of insects into the tissues slowly. The weaker the surface tension of the fluid, apparently, and the thinner the chitin with which it is in contact the more rapid the penetration. Gases and vapors may penetrate the chitin of insects, especially through the tracheae into the tissues far more rapidly than liquids.

"It is through absorption into the insect tissues of the volatile portions of kerosene, gasoline, creolin, pyrethrum and such contact insecticides that they mainly become effective agents against insects. Vapors from these insecticides enter the tissues and become effective long before the liquids as such have time to penetrate the chitin. Kerosene, miscible oils, etc., are able to enter the spiracles and tracheae of insects even when a 'closing apparatus' is present; but the comparatively rapid influence which such insecticides exert does not come from the plugging of the tracheae alone.

"The general effects of vapors from gasoline, kerosene, carbon disulphid, creolin, and the rest upon insects are very similar to the effects of the vapor of ether. The nervous system seems to be especially affected. Small amounts of such vapors produce, at first, more or less excitement; then a period of uncertain movements; and finally in larger amounts anesthesia or narcosis. The respiratory activity is usually increased until after the insects become deeply affected, and it is then depressed.

"Certain gases and vapors (*e.g.*, sulphur dioxid, ammonia and hydrocyanic acid gas) when present in respired air continue to be absorbed by insects while they are alive. For the most part, these gases are not given off when the insects are exposed to fresh air, but become rather firmly fixed within the tissues.

"Insect tissues quickly become saturated with any certain percentage of the vapor of carbon disulphid, carbon dioxid, kerosene, gasoline, or similar vapor and no more (at that percentage) is taken up. Then when the insects are exposed to pure air, practically all of such vapors or gases are given off from the tissues again—but not quite as readily as they were absorbed.

"Starvation, serious mechanical injury, and ammonia gas were all found to reduce the value of the respiratory quotient below the value given when healthy strong insects are breathing pure air.

"The vapors of gasoline, carbon disulphid, kerosene and To-bak-ine (*i.e.* nicotin), when present in sufficient amounts to bring the insects near death, cause the value of the respiratory ratio to rise above the value given by healthy, strong insects breathing pure air—*i.e.*, these vapors depress the activity of oxygen absorption more than they do the carbon dioxid excreting activity. The insects tried could continue to give off small amounts of carbon dioxid when no oxygen was present to be taken up, as when they were kept in tested nitrogen, hydrogen, or carbon dioxid.

"The evidence gathered seems to indicate that the vapors of gasoline, kerosene, carbon disulphid and the like, after absorption into the insect body, become mainly effective through some tendency their presence exerts to prevent oxygen absorption by the tissues.

"Lime-sulphur is a special rather than a general contact insecticide. Its strong, persistent reducing power, and its ability to soften the wax about the margin of a scale insect like the San Jose scale, are the important properties that make it efficient as a scalecide." *Expt. Stat. Record*, 1912.

"A contribution to our knowledge of insecticides," C. T. McClintock, E. M. Houghton and H. C. Hamilton (*Rpt. Mich. Acad. Sci.* x (1908), pp. 197–208, pl. 1, reprint).... "The work reported in this paper has to do with contact insecticides only....

"The insecticidal, germicidal, and toxic values (for higher animals) have little or no correlation. It is possible to determine the relative strength or value of insecticides

by immersing test insects in definite strengths of the insecticide, and noting the time required to produce death. The common bedbug (*Cimex lectularis*) appears to be the most satisfactory test insect. As yet the mode of action, the way in which the contact insecticides cause the death of the insects, has not been determined. Apparently, the fewer the number of spiracles, the smaller their size, and the better they are guarded by hairs or valves, the more resistant is the insect to the contact insecticides.

"Chemical standardisation of this class of insecticides is with our present knowledge impossible. With two substances, having essentially the same composition, the insecticidal values may vary enormously. Even the same substance, prepared with what are apparently unimportant chemical variations, gives widely different insecticidal values."

Relative efficiency of contact insecticides.

Kohlentear	125
As_2O_3 soap sol.	50
Terpentin säure	40
Schwafel säure	15
Nikotin	15
Leinol seife	5
KCN	5
Kresyl säure, seifen lösung	2·5
Karbol säure, seifen lösung	2·0
Morphin sulphat	2·0
Karbol säure, H_2O	1·0
$HgCl_2$	0·5
HgI	0·5
Formaldehyd	0·4
Alkohol	0·05

"A further contribution to our knowledge of insecticides," C. T. McClintock, H. C. Hamilton and F. B. Lowe (*Jour. Amer. Pub. Health Assoc.*, I (1911), No. 4, pp. 227–238, pl. 1): "It is possible to standardise substances which are subject to sophistication or deterioration by comparing the efficient dilution of their vapours with that of a product of known purity. This is particularly applicable to solutions of nicotin and to powdered chrysanthemum flowers. As yet there is nothing from which to conclude what action the vapours have on the insects. If it were merely irrative, formaldehyde would be valuable and the vapours of the burning insect powder without value. If the action were similar to anesthesia, chloroform should have been of greater value. If the action were purely that of poisoning one would have expected the highly poisonous hydrocyanic-acid gas to be of exceptional value for all species of insects."

These show that the way in which contact poisons act is not by any means clear, and that a great deal of research in insect physiology is required before we do know anything about it.

In conclusion, I wish to emphasise the practical bearing of this subject. I may have shed no light on it, but I do think that we owe it

to horticulturists to investigate these problems. The wetting of leaves and plant-buds is one point; the wetting or penetration of insects is another; the toxic action on insects is a third, and the last is to combine the three together in efficient insecticides that really do kill the insect every time and that cause a direct mortality of 100 per cent. In seeking an insecticide for woolly aphis, I would first seek a solvent of its wax. This is easy, but it is far from easy for instance with beech Coccus. In seeking an insecticide for apple sucker we first sought one that would wet apple buds. For mussel scale I would seek either a solvent of the secretionary part of the scale, or a liquid that would penetrate under the scale. These are protected insects, but what about naked insects such as bugs, aphides and the like; each has to be tackled individually. So too for stomach poisons. We know that we want to wet the leaves uniformily. Does lead arseniate and water wet well? I think not. In using lead chromate we add 25 % soft soap and 1·5 % of gelatine, simply to secure wetting; it is worth while as we use less liquid to get good even wetting and no dripping. What will wet one plant's leaf may not wet another. We know that for cabbages, for instance, but it is a factor seldom taken into account except with cabbages.

I hope I have shown that there is a field for research in this question. I wish we could get a satisfactory basis of reason on which to proceed, and not have to rely on empirical methods which really are not always successful. And I am inclined to think that in England too much reliance is placed on the tar and water principle to the detriment of the estimation in which applied Entomology is held by horticulturists and fruit growers.

THE COMPOSITION OF THE COFFEE BERRY AND ITS RELATION TO THE MANURING OF A COFFEE ESTATE.

By RUDOLPH D. ANSTEAD, M.A.,

Planting Expert, Agricultural Department, Madras, and Scientific Officer to the United Planters' Association of Southern India.

During the past five years I have been studying in Southern India the manurial problem as it affects coffee from a chemical standpoint with the object of trying to obtain some hint not only as to the best proportions of plant food to give this crop, but also at what time of year the plant food is best applied.

The first step was to investigate the composition of the mulch obtained from the shade trees and the coffee itself and to determine its manurial value. The result of our experiments was to show that under well-established mixed shade some four tons air-dry weight of mulch is accumulated per acre each year, and that this mulch contained 108 lbs. of nitrogen, 223 lbs. of calcium oxide, 36 lbs. of phosphoric anhydride, and 118 lbs. of potassic oxide per acre. From this it was concluded that the amount and composition of the mulch obtained annually from the shade trees was an important factor and should be taken into account when drawing up a manurial programme over a series of years, and also that it was quite possible that the coffee, where a heavy mulch was established as happens on many estates, was apt to receive an unbalanced ratio of plant food, the nitrogen being in excess with the result that leaf growth was encouraged at the expense of fruit.

Attention was next devoted to the chemical composition of the coffee berry itself. When an analysis of parchment coffee, or coffee berries, is examined it is at once noticed that potash is a dominant factor among the mineral constituents. This being so it is only logical to suppose that a fertiliser containing a preponderance of potash should help the coffee tree to ripen up and hold its crop, and the question at once presents itself as to when this potash should be applied. Do the coffee berries need it from the very beginning of their development,

as soon as they have set and the blossom has fallen, or do they need it only towards the end of their development? The same question also applies to the nitrogen and phosphoric acid. It seemed to us that if an answer could be found to these questions it would have a profound practical bearing upon coffee manuring practice.

During 1912 analyses were made of coffee berries each month from July to December throughout their period of development from the time they were quite small to the time when they were ripe and ready to pick and pulp. As it was found impossible owing to the press of other work to make a large number of analyses of different samples for comparison, and to get an average uniformity was attempted by taking a careful sample from a large number of berries of similar development carefully picked in the field.

The results of the analyses are shown in the following tables:

Analyses of Fresh Coffee Berries from July to January.

——	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.
Moisture	87·13	84·45	80·75	71·54	66·06	65·77	66·62
*Organic matter ...	11·96	14·67	18·18	26·93	32·05	32·48	31·58
Ash: Silica	0·04	0·01	0·03	0·02	0·02	0·04	0·05
Ash: Phos. acid ...	0·08	0·07	0·09	0·16	0·15	0·12	0·12
Ash: Potash	0·37	0·43	0·49	0·77	0·93	0·88	0·96
Ash: Lime	0·04	0·02	0·02	0·02	0·04	0·02	0·02
Ash: Other mineral matter	0·38	0·35	0·44	0·56	0·75	0·69	0·65
Total ...	100·00	100·00	100·00	100·00	100·00	100·00	100·00
*Containing nitrogen	0·30	0·38	0·24	0·50	0·61	0·67	0·66

Analyses of the Ash of Coffee Berries from July to January.

——	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.
Silica	4·48	1·48	2·84	1·23	1·11	2·47	3·03
Phos. acid	8·48	8·04	8·20	8·40	7·87	6·56	6·83
Potash	40·31	48·38	45·78	50·30	49·40	50·10	53·19
Lime	4·27	2·04	1·89	1·17	1·89	1·23	1·14
Other mineral matter	42·46	40·06	41·29	38·90	39·73	39·64	35·81
Total ...	100·00	100·00	100·00	100·00	100·00	100·00	100·00

The first table shows the actual composition of the fresh berries as regards the constituents named, while the second table shows the composition of the ash, that is the mineral part in each sample, it being chiefly this mineral matter with which we are concerned. In July the berries were very small and it required 72 of them to weigh one ounce. In December the berries were fully developed but still green or only just yellowing. At this stage the beans are developed and if pulped yield good coffee. In practice the berries are allowed to ripen and develop sugar, turning red in the process, in order to facilitate pulping and subsequent fermentation of the pulp adhering to the beans which enables the latter to be washed clean, the fermentation process having no effect upon the quality of the actual coffee bean. The last column in the tables is the analysis of the ripe berries as picked for pulping.

These analyses show that there is a markedly steady increase of potash content throughout the period of growth, and from this it is concluded that potash in an available form is needed all the time. The phosphoric acid content appears to be a constant quantity at first with a maximum about October after which it declines, hence it seems likely that this constituent is needed in an available form chiefly in the beginning of the season. The nitrogen content increases steadily throughout the period of growth and keeps pace with the increase of organic matter.

On these results a series of manurial experiments have been based and are now being carried out, but I should like here to especially call attention to the moisture content of the berries during their growth and development.

From July to December when the berries are fully developed in size there is a rapid and regular decrease in the amount of moisture in the berries. It falls from 87·13 % in July to 71·54 % in October and 65·77 % in December.

This confirms Mr H. B. Guppy's results. In his recent book *Studies in Seeds and Fruits*, he states that immature fruits contain more water than mature fruits, and that in the living plant or its part the decrease in the percentage of water is due to the fact that during the building up processes involved in growth the solids increase more rapidly than the liquid constituents.

During the ripening process, however, the moisture content increases by nearly one per cent., and this would appear to be a critical stage in the history of the berry.

Much more work is needed upon this point, but it is significant that

every year a certain amount of crop falls off and that in certain cases, on certain types of soil, the trees fail to hold their crop late in the season. This last year, 1913, was a dry one with also a large crop, and it was most noticeable that many of the berries failed to complete the last stage and would not ripen, but had to be picked and pulped while still hard and yellow instead of soft and red. The moisture factor has undoubtedly some bearing upon phenomena such as these, and it is possible that they can be controlled by methods of cultivation and the application of fertilisers which tend to increase the root area or conserve the soil moisture. The results so far obtained suggest at any rate interesting side lines of research, such as the above and the study of the physical condition of different types of coffee soils and their moisture content at different times of the year in the relation to the ability of the coffee grown on them to hold and ripen up a big crop.

THE LIFE-HISTORY AND HABITS OF THE GREENHOUSE WHITE FLY[1] (*ALEYRODES VAPORARIORUM* Westd.).

By E. HARGREAVES, A.R.C.Sc., D.I.C.

(*Imperial College of Science and Technology, South Kensington.*)

(With 56 Text-figures.)

This insect is commonly known as the "Greenhouse White Fly," from its general occurrence on greenhouse plants. It is classified as follows:

Family, *Aleyrodidae* ("Mealy wings"). Wings white, not transparent; antennae with seven segments; both sexes winged; tarsus with two segments.

Sub-order, *Phytophthires*. Antennae long and simple; tarsi with one or two segments.

Homoptera. Fore wings not thickened at the base; head bent over to touch the coxae.

Order, *Rhynchota* (Hemiptera). The mouth parts form a jointed beak (rostrum), bent under the thorax; two pairs of wings.

Aleyrodes vaporariorum has a wide range of food plants, and prefers potatoes, and such greenhouse plants as tomato, cucumber, melon, heliotrope, lantana, salvia. Although the flies and larvae are very small, they occur in such immense numbers that the plants become impoverished, and the quantity and quality of such fruit as tomatoes and cucumbers decreased. The whole of the under-side of the leaves is often completely covered with the scale-like larvae and pupae. They produce a large amount of excreta (honeydew), which falls on to the

[1] A paper on insecticidal treatment for White Fly has been delayed, pending the result of further work: Mr Hargreaves' departure for the United States prevented the second part of this paper, dealing with the treatment of White Fly, being completed. It will appear in an early number.

leaves below, inviting the prolific growth of fungi which ruin plants used for ornamental purposes. The adults prefer the young leaves for oviposition, and gradually ascend as the plant grows. Hence there will be green eggs on the newest leaves; a little lower, brown eggs; lower still the first stage larvae will predominate; below these the second stage larvae; and so on. Finally, on the oldest leaves, adults will be emerging. Occasionally eggs are laid on the stalks, flowers, and upper leaf surface; but they are generally laid in circles on the under-side, if the leaves are not very hairy and the insects undisturbed. The circle of eggs is made in a very ingenious way. The insect inserts its stylets into the leaf tissue and, using that point as centre and its body as radius, revolves as each egg is deposited. Hairiness of the leaves prevents this turning and the eggs are then scattered. The eggs are stalked, the stalk being short and partly embedded in the tissue of the leaf and arranged perpendicular to the leaf surface. They are green

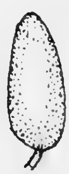


Fig. 1. Egg.

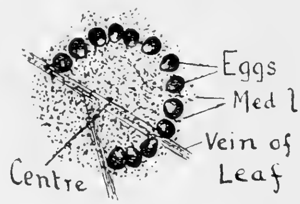


Fig. 2. Circle of eggs.

when first deposited and covered with the wax ("meal") produced by the adult, as also is the portion of leaf in the vicinity of the eggs. The circles of eggs are generally incomplete, with a diameter of about 1·5 mm., and I have not seen more than 15 eggs in one ring. (Length of stalk, 0·02 mm., total length of egg, 0·24 mm., greatest breadth, 0·70 mm.)

After two to four days (according to temperature, as I kept the humidity fairly constant) the eggs begin to darken in colour, turning from the original yellowish green to brown and finally to black. When nearing the time of hatching, which is about ten days after deposition, the meal drops off, leaving the egg smooth and shiny. The larva is visible inside, and its two eyes appear as bright red spots shining through the egg case near its free end. When about to hatch, the egg moves slightly from side to side, and two surfaces may now be distinguished: a convex, corresponding to the dorsal, and a concave, corresponding to the ventral surface of the larva. Hatching occurs ten to thirteen days after deposition. A crack appears near the free end of the egg on

its concave side (Fig. 3), and the anterior end of the larva emerges. The insect bends towards the leaf until it can get a hold, the legs, as they emerge, being used to push the egg-case free of the larva. The process

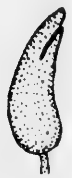


Fig. 3.

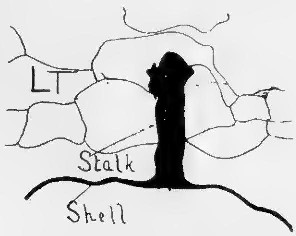


Fig. 4. Stalk of egg embedded in leaf.

is further assisted by flexure and alternate contraction and expansion of the abdomen. The empty egg-case is left standing on the leaf, collapsed.

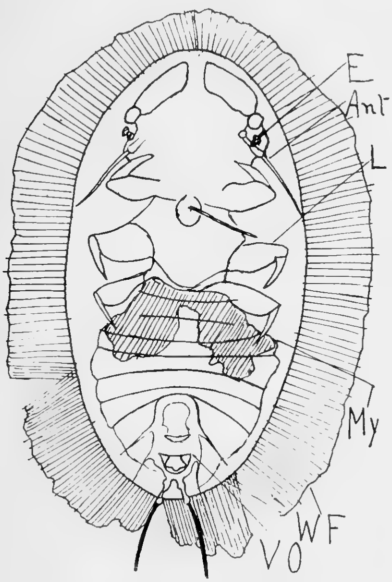


Fig. 5. First instar.

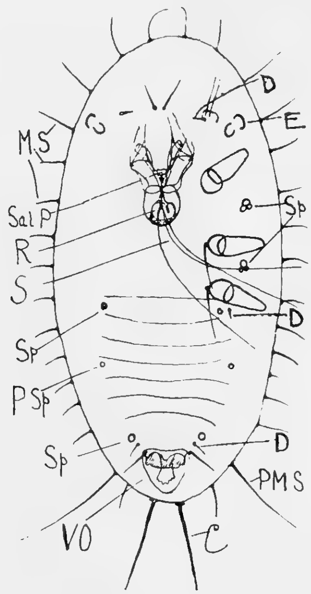


Fig. 6. First instar, from stained mount.

In an instance I observed, the time which elapsed from the appearance of the crack to the complete freedom of the larva was seventeen minutes.

Instar I (Fig. 5). The newly-emerged larva is very pale greenish yellow in colour, and the eyes, being bright red, are very obvious,

because of the contrast. Each eye is completely divided into two parts, each of which appears to consist of a single ommatidium. The larva is 0·29 mm. long, transparent, with a pair of dark yellow masses (present in all stages) in the abdomen, generally in the three or four anterior segments, but sometimes extending into the thorax. This pair of yellow masses is the mycetoma, or pseudovitellus. The segmentation of the abdomen is not distinct until a few minutes after emergence, when the chitin has hardened. There are six abdominal segments, but no differentiation in the thorax. The body margin has a series of spines (Fig. 6), fifteen pairs of which would seem to be segmentally arranged, since they are so arranged in the abdomen. Between the posterior two pairs is a pair of much longer spines; and posterior to all of these are the very long cerci (Fig. 7).

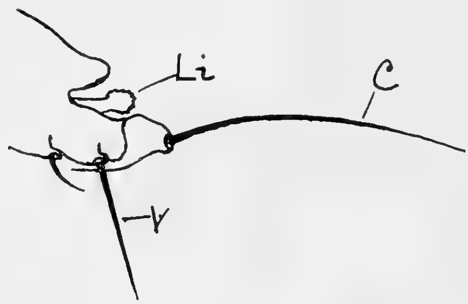


Fig. 7. Lateral view of hind end.

This larva is active for about three days, during which time it wanders about the under-surface of the leaf. It thus differs from some other species in which the larva simply gets clear of the egg before settling. Previous to settling down, or at about this time, the spaces between the marginal spines become filled in with wax formed by marginal wax glands.

The larva prefers a position alongside one of the leaf veins, and since the site it occupies is retained by the later instars, which are sedentary, the choice of this first larva is important. The waxy fringe is much wider in this stage than in the succeeding ones, and it gradually narrows in the succession. Behind the sixth abdominal segment, dorsally, is the vasiform orifice, the consideration of which I leave till later. Legs and antennae are functional during active life, and are well developed compared with those of the three later stages.

Mouth parts. There is a very short rostrum situated between the anterior legs. Two pairs of stylets correspond to the maxillae and

mandibles of other insects. The mandibles are outside (lateral to) the maxillae, which are fused along their length, forming by their union two ducts—a small posterior one for the passage of the saliva from the salivary pump to the leaf, and a larger anterior one for the passage of the food from the leaf. In the dorsal (anterior) wall of the pharynx is the cribriform organ, to which is assigned the function of tasting the food (sap) as it enters the mouth. The arrangement of the mouth-parts is similar in all the stages.

When the larva inserts its stylets into a leaf, in all the cases I have observed (by means of sections of leaves with the larvae *in situ*), the stylets go to the phloem cells of the vascular bundles, which contain

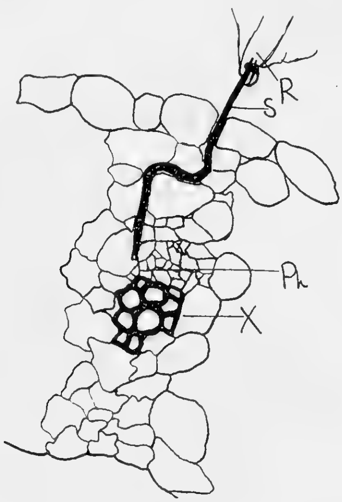


Fig. 8. Larval stylets in the leaf tissue.

proteids and albuminous materials—obviously the most suitable destination (Fig. 8). The entire sucking apparatus (viz. stylets, salivary pump, and chitinous structures in connection with them) is capable of a slight backward-and-forward movement, and this is the case in the next three instars also. As to the stylets themselves, they have a regular cycle of movements (Fig. 9), which is as follows. The mandibles (outer stylets) are thrust forwards (outwards) simultaneously, sliding on the maxillae (inner stylets). Their tips are incurved. They are then withdrawn one at a time, their curved ends scraping against the tips of the united maxillae, as if to bring food towards the latter to be sucked up.

Tracheal system (Fig. 10). This is very simple, there being interconnected dorsal and ventral systems, with very few small branches. This suggests that there may be some respiration through the skin. There are two pairs of thoracic spiracles situated, one pair between the anterior legs, the other between the posterior legs. Also there are two pairs of abdominal spiracles, one pair on the first abdominal segment,

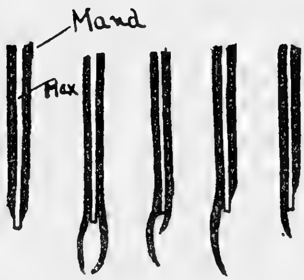


Fig. 9. Cycle of movements of stylets.

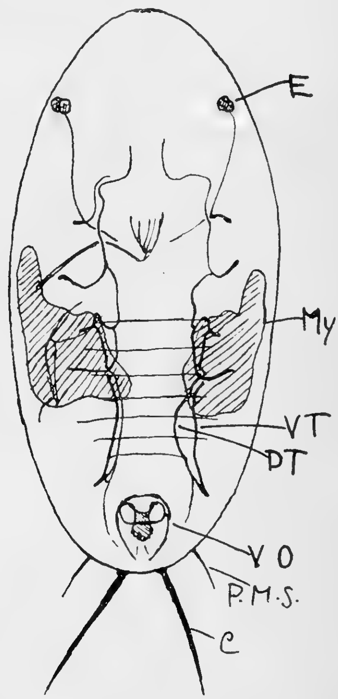


Fig. 10. Dorsal view of a mounted larva.

the other at the sides of the vasiform orifice. All the spiracles are ventral and placed upon elevations.

In preparations to show the tracheal system, there is seen a large vessel which ends suddenly in the fourth abdominal segment, without small branches. It is in connection with the dorsal system (Fig. 10). The larva is very small and the abdominal spiracles are in any case very difficult to observe. It is my belief that this large trachea indicates the presence of a spiracle which I have been unable to demonstrate with certainty. There is certainly an indication of a pair of ventral pores on the fourth abdominal segment.

Legs (Fig. 11). These consist of five segments, homologous, I should say, with the coxa, trochanter, femur, tibia and tarsus, of the legs of other insects. The coxa is small with a large spine on its inner side, and the trochanter comparatively large. The tibia has a large spine on its outer side at about the middle of its length. The tarsus is very small and seems to consist of two segments, the first one bearing a long curved spine externally, the second one terminating in a kind of pad, and possibly being the homologue of the pulvillus or paronychium of the adult, in which case it would not count as one of the actual tarsal segments.

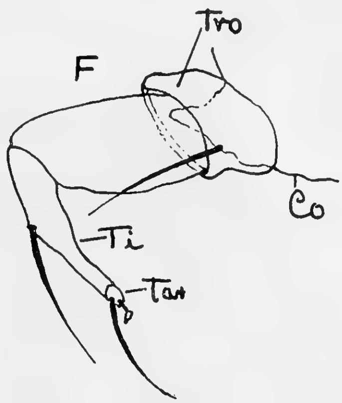


Fig. 11.

Antennae (Fig. 12). Each consists of three segments—the basal one is broad and short; the second is much longer and thinner, with a spine placed near the middle and another at the distal end. The terminal segment is twice the length of the second and terminates in a fine point; there is also a spine at about a quarter of the distance from the distal end.

Vasiform orifice (Figs. 13 and 14). In one of my mounts I was fortunate enough to obtain a side view, and was able to see the hind-gut opening dorsal to the lingula. The lingula is a finger-shaped organ, and just anterior to it, overlying the base, is a plate, the operculum. The anus opens between these.

Spines. In addition to the marginal spines there are five pairs situated as follows: a dorsal short pair over the anterior end of the mouth-parts; a ventral long pair near the middle of the mouth-parts; a ventral long pair beneath the corners of the vasiform orifice; a dorsal

short pair anterior to the vasiform orifice; a dorsal short pair in the first abdominal segment.

Fig. 12. Antenna.

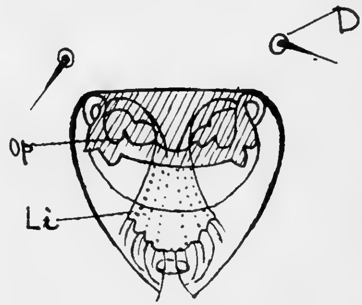


Fig. 13. Dorsal view of vasiform orifice.

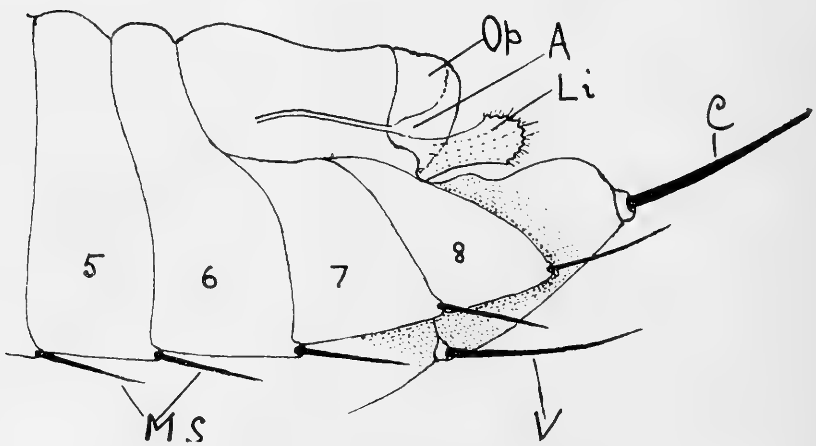


Fig. 14. Lateral view of hind end.

Instar II (Fig. 15).

This (and all stages previous to the imago) emerges from the anterior end of the old larval skin by pushing it off, partly with the aid of its short stumpy legs, but mainly by the flexure and alternate contraction and expansion of the abdomen. The eyes are bright red, and divided. When newly moulted, the larva flattens itself against the leaf, and, being transparent, is very difficult to see. It is a pale greenish-yellow in colour, with a length of from 0·37 to

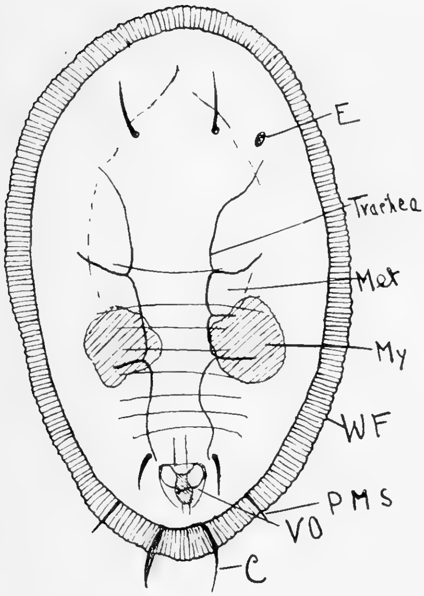


Fig. 15. Second instar.

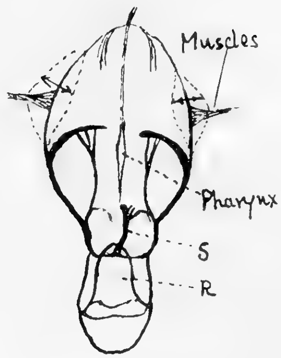


Fig. 16. Mouth-parts of second instar.

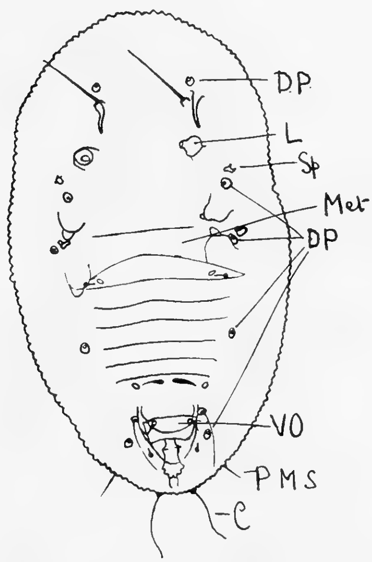


Fig. 17. Second instar.

0·39 mm. A very noticeable feature is the great increase in size (length and breadth), which has taken place at the moult. (This also applies to the two succeeding stages.) The rostrum is more pronounced than in the previous stage (Fig. 16), but the general arrangement of the mouth-parts is the same. This larva generally retains the same position as the last, but I have observed one to move slightly immediately after

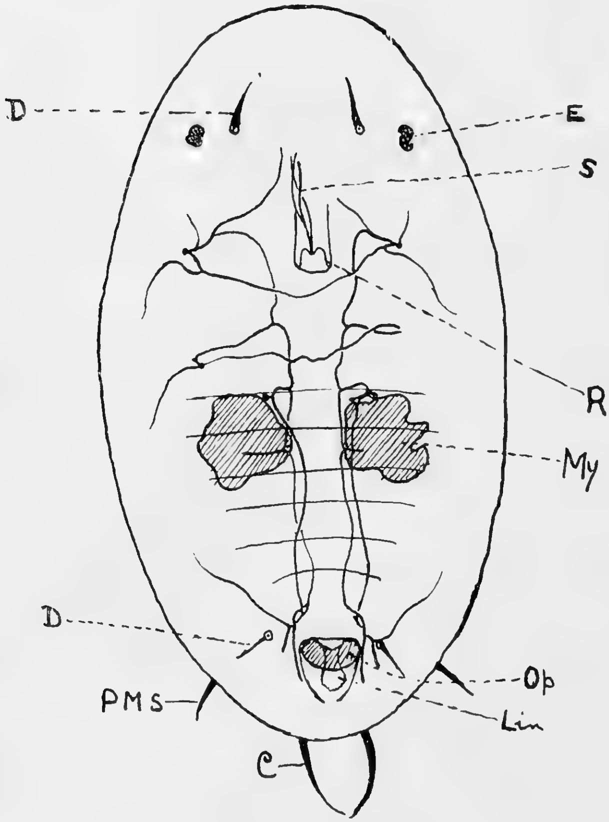


Fig. 18. Second instar.

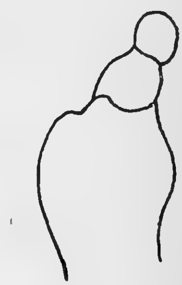


Fig. 19. Leg of second instar.

emergence. The margin is at first entire except for the cerci and the pair of more anterior spines, both being shorter than in the previous stage. Later, however, a waxy fringe is developed. When this is dissolved, the body margin is seen to have become crenulated (Fig 17). There is a metathoracic and six abdominal segments differentiated.

Tracheal system (Fig. 18). There are dorsal and ventral systems which are connected, and very few small branches are present. There

are two pairs of thoracic spiracles arranged as in the preceding stage, and two pairs of abdominal situated in the first segment and at the sides of the vasiform orifice respectively. A pair of thick tracheae are given off from the dorsal system with evidence of a pair of spiracles, as in the first instar.

Legs (Fig. 19). The legs are much smaller than in the first instar, and they are functionless as ambulatory appendages. Each consists of three segments the homology of which could not be determined with certainty. But it seems probable that the trochanter and tarsus are absent. No spines are present.

Antennae (Fig. 20). The antennae are exceedingly small, and each is made up of two segments, the basal one having a short spine near the middle, and the distal one being covered with very short hairs.

Fig. 20. Antenna of second instar.

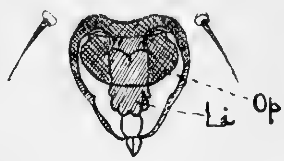


Fig. 21. Vasiform orifice and ventral spines.

Spines (Fig. 16). In addition to marginal spines there are—a long dorsal pair over the anterior end of the mouth-parts; a short dorsal pair on the first abdominal segment; a long dorsal pair at the anterior corners of the vasiform orifice; a very short pair at the posterior sides of the vasiform orifice; a short ventral pair beneath the vasiform orifice.

Vasiform Orifice (Fig. 21).

Dorsal pores (Fig. 17). On the dorsal surface are six pairs of pores, which I take to be the openings of the wax glands, the secretion of which covers the general surface of the body. They have a peculiar and characteristic appearance. My preparations were stained with acid fuchsin, and the pores appeared as small dark red rings, surrounded by an area which was of a paler pink colour than the surrounding chitin of the general surface. They are situated as follows: a pair in front of the anterior dorsal spines; a pair each near the thoracic and first abdominal spiracles; a pair in the fourth abdominal segment; a pair at the sides of the vasiform orifice.

Instar III (Fig. 22).

General appearance and habits as in the preceding stage, but larger, with the wax fringe narrower and the marginal spines shorter. It is 0·52 mm. in length, with six abdominal segments, and the metathorax differentiated. Mouth-parts of the same general structure as in the first and second instars.

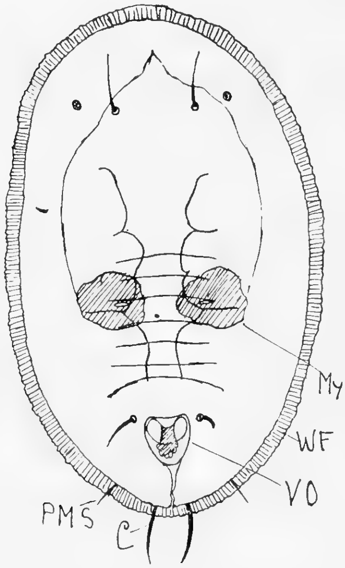


Fig. 22. Third instar.

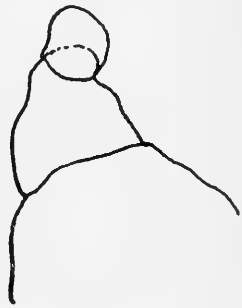


Fig. 23. Leg.

Fig. 24. Antenna.

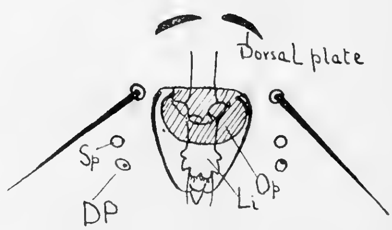


Fig. 25. Vasiform orifice.

Tracheal system. As in the previous stage.

Legs (Fig. 23). The legs are very small, functionless for locomotion, and the structure as in the preceding stage.

Antennae (Fig. 24). Each consists of two segments. The basal one is broad and carries a spine distally; the second is hairy and characteristically hooked.

Vasiform orifice (Fig. 25).

Spines. In addition to marginal, are four pairs arranged—a long dorsal pair over the anterior end of the mouth-parts; a dorsal short pair on the first abdominal segment; a dorsal long pair at the anterior angles of the vasiform orifice; a ventral pair beneath the vasiform orifice.

Dorsal pores. Twelve pairs situated—a pair over the sides of the mouth-parts near the middle line; a pair anterior to the bases of the antennae, and a pair just anterior to them; a pair near each pair of thoracic spiracles; a pair towards the middle of the first abdominal segment; a pair each in the third, fourth, fifth and sixth abdominal

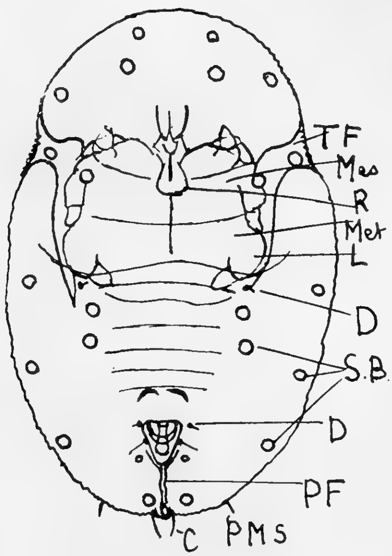


Fig. 26. Fourth instar.

segments; a pair immediately posterior to the sixth abdominal segment; a pair at the sides of the vasiform orifice.

Breathing folds. There is a pair of these folds opening opposite the anterior pair of spiracles, and the lumen of each extends alongside the thorax to the first abdominal segment. I could not find a posterior fold. (See below.)

Instar IV (Fig. 26).

This stage, which may be taken to be the equivalent of the pupal stage of other insects, differs very much in appearance from those preceding. When newly emerged there are eleven pairs of

large round spine-bosses to be seen, situated: seven pairs near the margin, a pair towards the middle line anteriorly, a pair in the thorax, and a pair in each of the third and fourth abdominal segments. Later, the glands at these points give rise to long waxy processes (Figs. 26, 27), the arrangement of which is made use of in systematic work. Like the preceding stages, this instar is at first transparent and a pale greenish-yellow in colour and has small red eyes. The length varies from 0·7 mm. to 0·82 mm. It differs from the others in that much growth in length, breadth and thickness takes place. There are six abdominal and two thoracic segments differentiated. The body margin is at first entire, except for the cerci and posterior spines, which are shorter than those in the preceding stage. Later, waxy processes are developed along the margin generally to the number

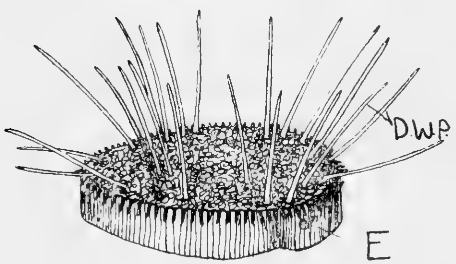


Fig. 27. Fourth instar.

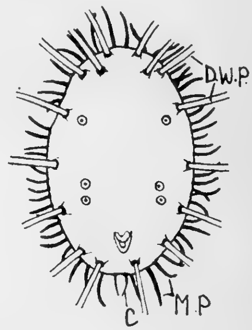


Fig. 28. Fourth instar.

of 38 pairs (Fig. 28). The mouth-parts are similar in structure to those in previous stages.

Tracheal system (Fig. 29). This is much more complicated than in any previous stage, as numerous fine tracheal ramifications are present. There are dorsal and ventral systems, which are in connection.

Spiracles (Fig. 29). There are four pairs of spiracles situated as follows: a pair in the metathorax; a pair of more anterior thoracic; a pair in the first abdominal segment; and a pair at the sides of the vasiform orifice.

Legs (Fig. 30). They are not functional for walking, and consist of three segments, the basal one being very broad. No spines are present.

Antennae (Fig. 31). Each consists of two segments, the distal one terminating in a rather fine point.

Spines. In addition to the marginal and the eleven pairs of long dorsal spines mentioned above, there are: a pair ventral to the vasiform

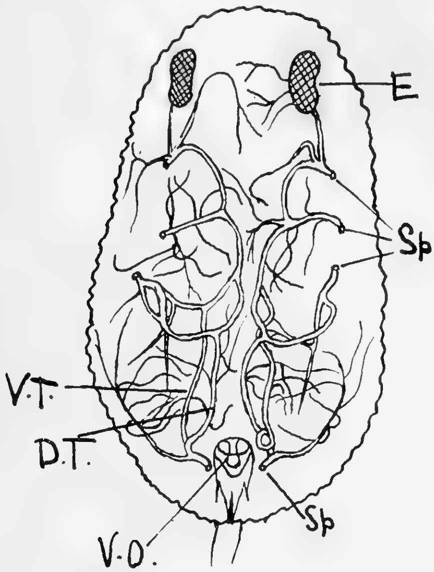


Fig. 29. Fourth instar, tracheal system.

Fig. 30. Leg.

orifice; a dorsal pair at the anterior corners of the vasiform orifice; a dorsal pair in the first abdominal segment; an anterior dorsal short pair over the sides of the mouth-parts.

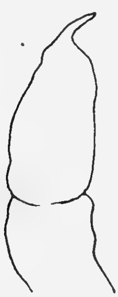


Fig. 31. Antenna.

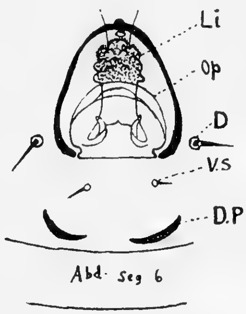


Fig. 32. Vasiform orifice.

Dorsal pores. There are twelve pairs arranged as in the previous stage.

Vasiform orifice (Fig. 32).

Breathing folds (Figs. 26, 33). There is a pair of anterior folds opening ventro-laterally opposite the anterior pair of thoracic spiracles. They are continued alongside the thorax to the first one or two abdominal segments. In the living insect, the passage leading to the exterior

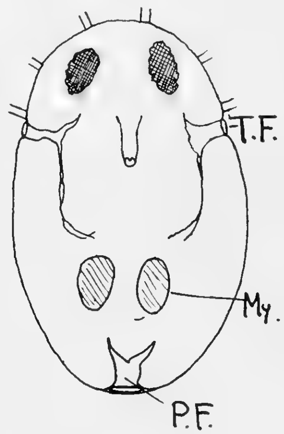


Fig. 33. Ventral view of fourth instar.

appears to be a tube (Fig. 33), the floor of which is formed of wax, so that in specimens which have been treated with a wax solvent, the tubes have become simply grooves (Fig. 26). There is also a posterior fold extending from the middle of the posterior margin to the vasiform

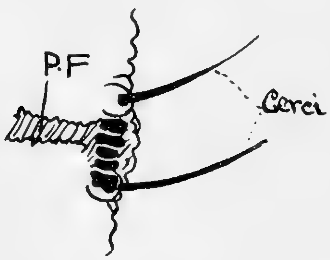


Fig. 34. Opening of posterior fold.

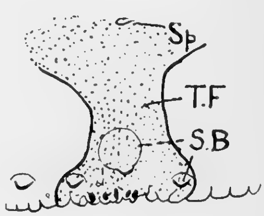


Fig. 35. Opening of thoracic fold.

orifice, which communicates with the posterior spiracles. The character of the margin at the external openings of these folds is peculiar (Figs. 34, 35). Later, the body shrinks away from the cuticle, and the development of the adult organs (eyes, wings, legs, etc.) begins. In sections

at this stage two layers of chitin are to be distinguished, one being that which originally enclosed the fourth instar, the other, inside this, which is destined to be the adult skeleton (Fig. 36). This may be called an

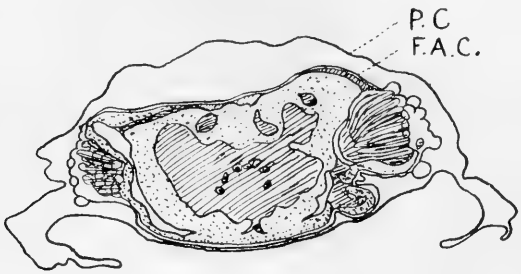


Fig. 36. Section through head of fourth instar.

internal moult. The eyes, from being mere spots in the young pupa, grow enormously to form the compound eyes of the imago. The body grows very much in thickness, becoming box-like in the older pupa (Fig. 27). Also, the antennae, legs and wings may be seen curled up inside the outer case, but outside the body of the insect. As is the case in the preceding stages, the new legs and antennae are formed inside the old ones, and since those of the imago are much longer than those of the pupa, they become folded as they grow. The claws and second tarsal segment easily fill one of the pupal legs (Fig. 37). The

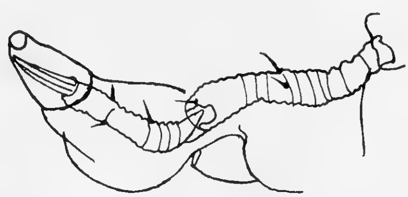


Fig. 37. Adult leg developing in pupa.

wings are outgrowths of the inner layer of chitin, the growth being continuous and gradual and thus differing from that which takes place at successive moults, in steps as it were, in some other insects. So far as I can make out, the wings arise as evaginations, and not as invaginations, which are later evaginated as in insects like the *Lepidoptera*.

Instar V (Fig. 38).

This is the final stage, or imago. It emerges from a T-shaped crack, the crossbar dividing the pupal abdomen from the thorax,

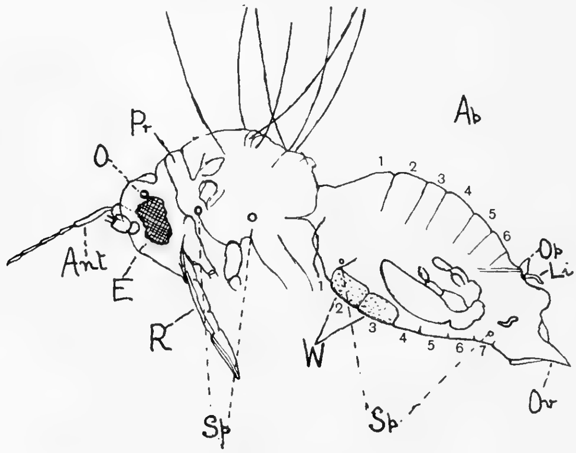


Fig. 38. Adult.

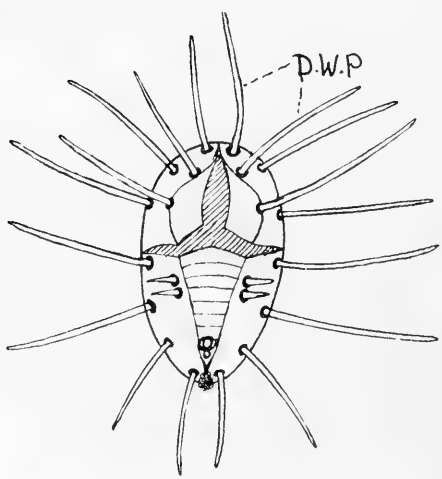


Fig. 39. Empty pupa-case.

the vertical bar being median, and extending from the crossbar to the anterior margin (Fig. 39). The thorax is the first part to emerge; then the head, with the rostrum and antennae, which gradually

straighten out and harden. The legs are then successively drawn out and straightened, and simultaneously with this the rest of the thorax, bearing the wings which are curled up on each side. When the legs have hardened, the insect uses them to push at the pupa case for the extraction of the abdomen. It takes an hour or so for the wings to become straight. The newly emerged imago is quite devoid of any waxy covering, but after some time, its body and wings become covered

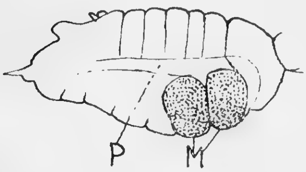


Fig. 40. Adult's abdomen, lateral.

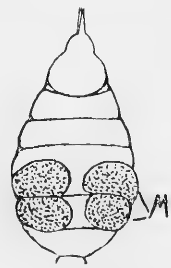


Fig. 41. Adult's abdomen, ventral.

with the white substance (meal, or wax), from which the names "white-fly" and "mealywing" are derived. It varies in length from 0·95 mm. to 1·4 mm. I placed a newly emerged female insect on a slide beneath a coverslip in order, if possible, to observe where the wax was formed. After some time, I found that two pairs of plates were covered with it. These are situated ventro-laterally on the second and third abdominal

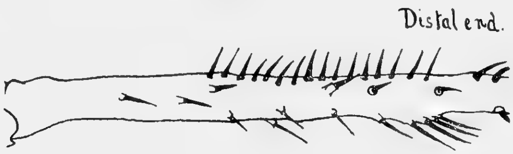


Fig. 42. Part of hind tibia.

segments (Figs. 40, 41). The rest of the body was quite clean. On careful observation of one of the flies while on a leaf, by means of a binocular, I saw that it scraped its abdomen with the tibiae of its hind legs, and then stroked them on its wings, and the remainder of the abdomen. Similarly, it uses its fore-legs for the head and thorax. On the hind tibia is a row of stiff setae, which act as a comb for the transference of the wax (Fig. 42). There are four pairs of wax plates

in the male, situate in the second, third, fourth and fifth abdominal segments. The meal has a peculiar structure, being in the form of spirals or parts of spirals, as if it had been forced through small openings (Fig. 43). In thin sections (Fig. 44), taken through the region of these wax glands, there is seen a single layer of secreting cells with large nuclei, and containing vacuoles from which the wax has been dissolved during preparation. There are also numerous granules which are more numerous towards the exterior. The overlying chitin at first appears to consist of a series of imbricated plates, which effect, however, is due to the presence of small pores, thus giving the chitin that striated appearance.

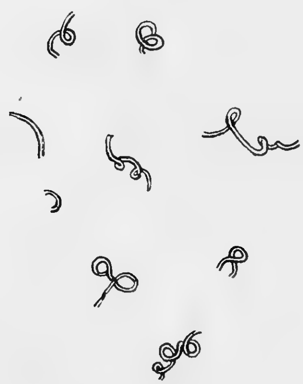


Fig. 43. Wax threads.

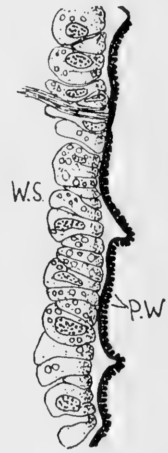


Fig. 44. Section through wax glands.

[In order to determine with certainty the structure of the chitin, special precautions as to lighting, to prevent error from reflection or aberration, were found to be necessary, because of the high magnification required.]

Antennae (Fig. 45). Each antenna consists of two broad segments at the base and five longer and more slender ones. They are placed just in front of the eyes, and show pseudo-segmentation. On each of the third, fifth and seventh segments, situated on their distal ends and on the dorsal (anterior) side, is a circular pit fringed by setae. These are probably olfactory organs. The seventh segment terminates in a fine point. The length of the antenna is 0·36 mm. in the male, and 0·32 mm. in the female.

Rostrum (Figs. 38 and 47). The rostrum is a prominent structure equivalent to the labium of other insects, and consists of three segments, with an imperfect joint again dividing the middle one. On its anterior

Fig. 45. Antenna.

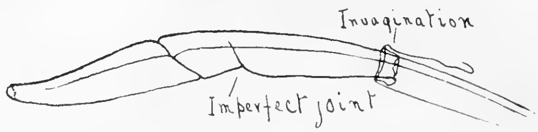


Fig. 46. Rostrum.

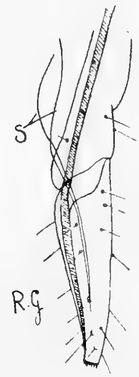


Fig. 47. Rostrum.

surface is a deep groove, extending along its whole length, for the reception of the stylets. The tip is sharply serrated, presumably to enable the insect to get a grip on the leaf surface during insertion of

the stylets. The rostrum may be drawn into the head to such a great extent that the dorsal end of the groove nearly reaches the dorsal wall. It may also be invaginated upon itself like a glove finger (Fig. 46). These arrangements are for the insertion of the stylets, insomuch as the rostrum is longer than the stylets. The portion of stylets outside the plant is completely enclosed in the groove. Hence the rostrum functionally shortens as the stylets are inserted. There is no arrangement in the head for the retraction or expulsion of the stylets themselves. When the insect is not feeding, the stylets are completely enclosed in the rostral groove.

Eyes (Fig. 48). The eyes of the adult are compound, and each is divided externally by an area covered with short hairs, into lower and

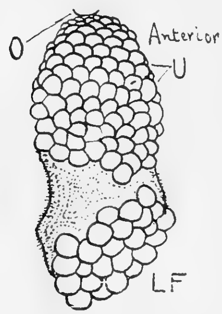


Fig. 48. Eyes.

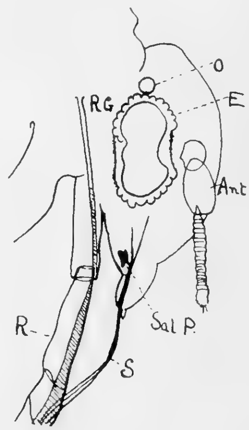


Fig. 49. Side view of head.

upper portions, the upper having smaller facets than the lower. They are very large, and just above each is an ocellus (Fig. 49). The two parts of each eye unite inside the head.

Mouth-parts. The mouth-parts have the same general structure as in the preceding stages, but there is one great difference. In the larvae the stylets may be withdrawn inside the body (Fig. 50), probably into a pouch as in Monophlebus (Coccidae). The mandibles are not fused, either with themselves or with the maxillae, and they may slide upon the latter. They are very slender structures without teeth or serrations.

Segmentation (Figs. 38 and 40). The attachment of the abdomen to the thorax is very narrow. From the dorsal surface small prothoracic and large meso- and meta-thoracic segments are visible. Behind

the six abdominal segments which are to be distinguished dorsally, is a portion in which the vasiform orifice is situated, and which terminates as ovipositors in the female and claspers in the male. There are seven

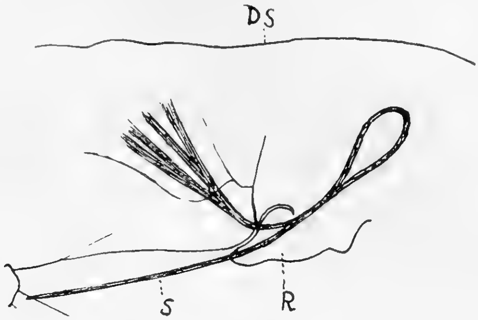


Fig. 50. Stylets of first instar.

abdominal segments visible ventrally. Along each side of the abdomen is a narrow band of thin chitin consisting of the pleura of the segments (Fig. 40).

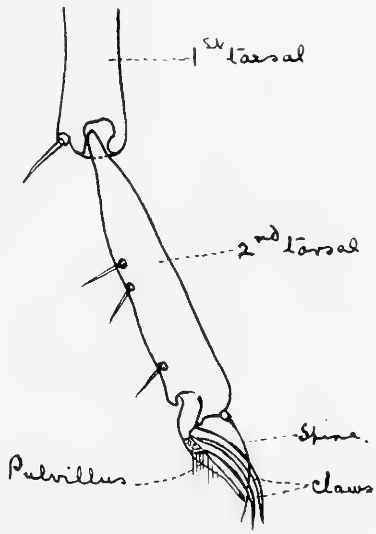


Fig. 51. Tarsus.

Legs. The third pair of legs are the longest and the first the shortest. Each consists of a coxa, trochanter, femur, tibia and a tarsus of two segments. Articulating with the second tarsal segment is a small piece supporting two long curved claws and a median hairy and pointed pulvillus (paronychium) (Fig. 51). There is also a long curved spine

attached independently to the distal end of the second tarsal segment.

Wings (Figs. 52, 53). There are two pairs of wings in both male and female, and the venation of both fore and hind wings is exceedingly simple. There is a series of knob-like structures running round the wing margin, each knob supporting two or three hairs (Fig. 54).

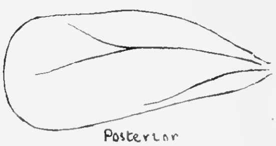


Fig. 52. Fore wing.

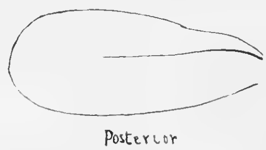


Fig. 53. Hind wing.

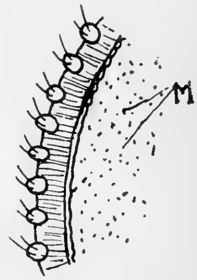


Fig. 54. Wing margin.

Tracheal system. The tracheal system is very complicated, as in the pupa, and there are four pairs of spiracles situated as follows: a pair each in the pro- and meta-thorax; a pair on the first abdominal segment placed a little antero-dorsal to the anterior pair of wax plates; a pair on the sides of the vasiform orifice, ventro-laterally.

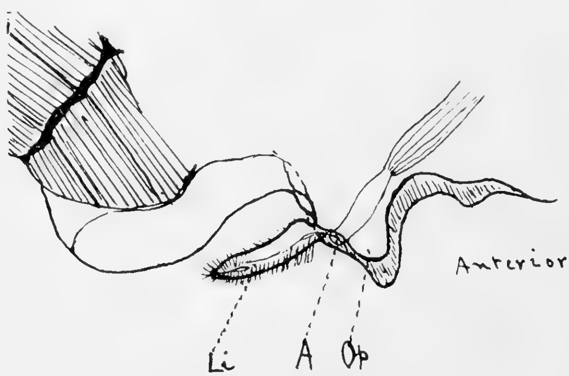


Fig. 55. Vasiform orifice.

[Quaintance[9] in his *Classification of the Aleyrodidae,* states that there are three pairs of thoracic spiracles in the *Aleyrodidae.* Woodworth[4], in *A. citri,* had also described three pairs.]

Vasiform orifice (Fig. 55). The function of this peculiar apparatus

appears to be to get rid of the excreta (honeydew). The lingula moves in a vertical plane, while the operculum moves slightly backwards and forwards. The anus opens on the dorsal surface of the lingula (anterior to it) (Fig. 55). Ventral to the base of the lingula is a cleft, which is presumably to allow the lingula greater freedom of movement. Leading from the base of the lingula near the anus to its tip is a row of rather long setae, and at the tip there is a depression surrounded by them. It would appear that the honeydew is conducted from the anus *via* the row of setae, to the tip of the lingula, in the depression of which it can accumulate and form a globule. It is got rid of by the flicking of the lingula. This flicking is easily seen in the case of the pupa. The honeydew on exposure becomes gradually more and more viscous, and if it were not for the above arrangement the anus would become occluded, and the insect killed. The position of the anus corresponds

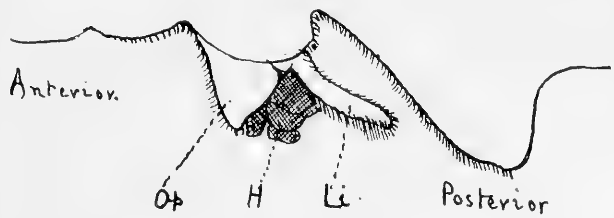


Fig. 56. Vasiform orifice with solidified honeydew.

with the general up-side-down habit of the insect on the under leaf-surface. In some of my preparations there is a mass of clear structureless material filling in the space between the lingula and operculum. This is honeydew which had become so viscous that the insect could not get rid of it (Fig. 56). It may be that the fly had remained in an upright position for some time.

Peal[5], 1903, considered that the lingula secreted the honeydew.

Miss Bernis[6] (*Proc. U.S. Nat. Mus.*, vol. XXVII, p. 475) supports Peal.

Quaintance[9] could not find a definite opening at the tip of the lingula, and states that whether the anus opens at the base or tip, the lingula functions as the supra-anal plate. He homologises the lingula with the supra-anal plate of the Psyllidae, where the anus opens at the tip.

The small numerals refer to the bibliography. 3, 5, 6, 7, 8, and 9 are quoted from Quaintance 1913.

Duration of the various stages.

Egg. Green when laid. Turn brown in two to four days. Hatch in 11 to 14 days from deposition. Mean of 13 cases, 11 days.

Instar 1. Active for two to four days, wandering about the leaf. Duration 10 to 12 days. Mean of 13 cases, 11 days.

10, 10, 10, 10, 11, 11, 11, 11, 11, 12, 12, 12, 12.

Instar 2. Inactive. Duration 14 to 22 days. Mean of ten cases, 17·8 days.

14, 14, 14, 14, 16, 19, 21, 22, 22, 22.

Instar 3. Inactive. Duration five to 36 days. Mean of 20 cases, 18 days.

5, 5, 5, 7, 7, 8, 10, 10, 14, 18, 21, 22, 23, 26, 27, 27, 27, 33, 33, 36.

Instar 4. Inactive. Pupa. Duration 21 to 59 days. Mean of 17 cases, 37 days. The pupa turns slightly yellow before emergence of the imago.

21, 24, 24, 24, 25, 26, 31, 40, 41, 42, 47, 47, 51, 53, 53, 59, 40.

Instar 5. *Imago.* Duration. The longest was 38 days, which was during cold weather.

The weather regulates the duration of all stages, except the egg, which is not affected. Cold weather increases the time, making them live more slowly.

Summary of Duration of the various Instars.

Stage	Cases taken	Mean
Egg	13	13 days
Instar 1	13	11 ,,
,, 2	10	18 (17·8)
,, 3	20	18 ,,
,, 4	17	37 ,,

Life Histories.

Egg laid	Hatch	Moult 1	Moult 2	Moult 3	Imago
16 Oct.	29 Oct.	6 Nov.	23 Nov.	19 Dec.	23 Jan.
18 ,,	30 ,,	9 ,,	27 ,,	24 ,,	27 ,,
16 ,,	28 ,,	4 ,,	25 ,,	22 ,,	23 ,,
16 ,,	30 ,,	10 ,,	1 Dec.	24 ,,	23 ,,
16 ,,	27 ,,	10 ,,	27 Nov.	30 ,,	23 ,,
16 ,,	30 ,,	10 ,,	26 ,,	19 ,,	9 ,,

Parthenogenesis. I placed three females, isolated before complete emergence so as to be absolutely certain that they had not been fertilised, each on a clean plant. From these I obtained ten, thirteen and twenty imagos respectively, all females. From these I got females again, and out of the hundreds of flies which I examined I did not encounter a single male.

Morrill[8] on parthenogenesis in the *Aleyrodidae*, states that unfertilised eggs hatch giving larvae which result in male flies, and suggests that the fertilised eggs will all give rise to females, as in bees. Morrill and Back further established parthenogenesis in *Aleyrodes citri*.

Some General Notes.

Spiracles. There is evidence for the presence of three pairs of abdominal spiracles in the first three instars. In the other two, however, there is not. It might be suggested that this reduction during development is some indication that an ancestor of the *Aleyrodidae* had a pair of spiracles in each abdominal segment. These may possibly be developed in the embryo, all except the remaining three being absorbed before hatching.

Breathing folds. In the case of the instars which are fixed in one place during their existence, viz. the second, third and fourth, they are fixed to the leaf by the waxy fringe. Since the spiracles are ventral, there must be some arrangement for the access of air. This requirement is met by the "breathing folds." On each side of the thorax, opposite the first pair of thoracic spiracles, the ventral body-wall is transversely folded, the fold being continued along the sides of the thorax and part of the abdomen. This allows for the access of air to the thoracic and first abdominal spiracles. The animal forms a floor of wax to these folds, thus converting them into tubes (Fig. 33). The margin at the openings of these differs from the rest (Figs. 34, 35). There is a similar median longitudinal one posteriorly for the access of air to the spiracles on the sides of the vasiform orifice. In the first larva, either the folds are absent, or are too small for observation. But there may be other arrangements in this case, if such are required. In the first place, I have seen a few of the larvae walking about after the formation of the waxy fringe, which suggests that the fringe is not in contact with the leaf. This would obviate the necessity of breathing folds. Also, there is a long spine on the inside of the basal joint of each leg, and a pair of long ones beneath the vasiform orifice. These may function as resting

spines. These long leg-spines are absent in the other stages, and those beneath the vasiform orifice, if present, are short.

When larvae are nearing the moult, they become fat and lose their close contact with the leaves, so that they are then easy to see. The first three instars do not grow in length during their existence, this taking place entirely at the moult; but they grow in thickness (dorso-ventrally). Thus, the length for each of these three instars is constant, and it may, therefore, be used as a criterion of the stage. It varies within $2\,\mu$ only. The fourth instar (pupa), however, grows considerably ($12\,\mu$) in length, and also very much in thickness (Fig. 27).

The *honeydew* on exposure becomes very viscous, so that any stage which feeds for any considerable time with its dorsal surface upwards, is quite likely to have its anus clogged, as is the case in some of my whole mounts of adults. In these cases the plug of honeydew is situated on the dorsal side of the lingula, thus confirming the dorsal position of the anus with relation to the lingula, which I demonstrated both in a whole mount and by means of sections.

Dorsal pores. On the dorsal surface of the second, third and fourth instars are small pores, those in the abdomen and thorax being segmentally arranged. They are probably pores for the passage to the exterior of wax formed by the underlying cells, the body being covered with it. But it is not a white powder or meal as in the adult.

It may be asked: Why are all the stages generally on the underside of the leaves? The following points require consideration:

(1) The character of the cuticle of the leaf.
(2) Presence of stomata.
(3) Protection from wet.
(4) Phototropism.
(5) Position of the anus and character of excreta.

(1) The cuticle is certainly thinner, and the vascular bundles are nearer the surface, on the underside of the leaf.

(2) In all the sections of larvae *in situ* that I have examined, in no case do the stylets penetrate a stoma.

(3) All the stages have a waxy covering, so that the position as a protection from wet would appear to be a subsidiary matter.

(4) If a leaf with flies on the under-surface is turned over, after a time all the flies migrate to the other side and may lay eggs there. This fact excludes points (1) and (2). If a leaf hangs with its surface in a vertical plane, the females do not show any preference of leaf-surface for oviposition. To catch the flies, I turn a leaf over, and, holding a

specimen tube over a fly, touch it with the edge of the tube. It may behave in two ways: either it flies immediately upwards into the tube, or it simply falls over on its side feigning death. If a fly is touched while the leaf is in the normal position, it does not generally immediately take to flight, but drops for three or four inches, and then flies quickly away from the plant. If a number of the flies are placed in a tube, they all congregate at the upper end. This seems to be an attempt to get into the position with the dorsal surface downwards, and not a result of phototropism. I placed some flies in a tube, and, as usual, they congregated at the upper end. So I covered all the tube except the lower part to exclude the light, and placed a Nernst lamp beneath, so that the light was shining upwards into the darkened tube. It did not, however, cause the flies to come to the bottom of the tube, which indicates that they are not positively phototropic. And their general behaviour points to their not being negatively phototropic.

(5) I consider that the situation of all the stages on the under leaf-surface is correlated with the dorsal position of the anus. The following considerations lead me to this conclusion:

If the insect were dorsal surface upwards

(*a*) it would be unable to get rid of its excreta, which would clog the anus, or, accumulating on the leaf and becoming viscous, would occlude the spiracles,

(*b*) any accumulation of honeydew (excreta) is a very suitable medium for the growth of Fungi,

(*c*) the newly-hatched first larva would become entangled in the viscous excreta which fouled the leaf and would be unable to settle down,

(*d*) the various larvae when moulting would have difficulty in casting off their old skins.

Enemies. Now as to the enemies of the insect. I have not encountered any animal parasites as yet, either of the nymphs or the adult. On one occasion I caught a mite which was holding and devouring a living fly. Spiders also prey on them. On one leaf a spider was discovered surrounded by the remains of half-a-dozen of the flies. Fungi occasionally kill both adults and nymphs.

Methods of eluding predaceous enemies. (1) Escape by dropping, and flight.

(2) Transparency of the larvae is probably a factor in this, as it renders them practically invisible.

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EXPLANATION OF FIGURES.

All figures are drawn at stage level with tube length of 150 mm. Leitz oculars and objectives throughout.

Figs. 10, 15, 17, 18, 22, 46, 49, Oc. 1, Ob. $\frac{1}{6}$.

Figs. 1, 3, 29, 38, Oc. 3, Ob. $\frac{1}{3}$.

Figs. 5, 6, 7, 16, 21, 25, 30, 32, 34, 36, 37, 42, 45, 47, 48, 51, 55, 56, Oc. 3, Ob. $\frac{1}{6}$.

Figs. 4, 8, 11, 12, 13, 14, 19, 20, 23, 24, 31, 43, 44, 50, 54, Oc. 3, Ob. $\frac{1}{12}$ (oil imm.).

The following are reduced:

Figs. 12, 15, 17, 25, 31, 32, 35, 37, 38, 42, 44, 46, 48, 50 to $\frac{2}{3}$.

Figs. 4, 5, 6, 8, 22, 45, 47, 49 to $\frac{1}{2}$.

Fig. 1. Egg.

Fig. 2. Circle of eggs. Note surrounding meal.

Fig. 3. Egg showing crack for emergence of larva.

Fig. 4. Section of egg *in situ* on the leaf.

Fig. 5. Ventral view of living first instar. Note the broad fringe of wax, cerci, legs, antennae, eyes, stylets, mycetoma, segmentation.

Fig. 6. Ventral view of stained preparation to show spiracles, mouth-parts, eyes, marginal and other spines.

Fig. 7. Lateral view of posterior end of abdomen to show the length of the cerci.

Fig. 8. Larval stylets in the leaf tissues.

Fig. 9. Cycle of movements of stylets.

Fig. 10. Dorsal view showing tracheal system. Note dorsal and ventral parts.

Fig. 11. Leg of first instar from the outer side. Note the basal spine on the inner side.

Fig. 12. Antenna.

Fig. 13. Dorsal view of vasiform orifice.

Fig. 14. Lateral view of posterior end of abdomen of first instar showing vasiform orifice. Note the anus opening between the lingula and operculum, and marginal spines.

Fig. 15. Dorsal view living second instar. Note wax fringe, cerci, and pair of posterior marginal spines.

Fig. 16. Mouth-parts of second instar. Note peculiar folded rostrum, short length of protruding stylets, dilated pharynx with the dilator muscles and their direction of action (indicated by arrows).

Fig. 17. Dorsal view second instar, showing spiracles, dorsal pores, crenulated margin, etc.
Fig. 18. Ventral view showing tracheal system, mycetoma, eyes.
Fig. 19. Leg. Note spine on basal segment and hairy terminal one.
Fig. 20. Antenna.
Fig. 21. Ventral view vasiform orifice and adjacent spines.
Fig. 22. Dorsal view living third instar, to show the narrow wax fringe, cerci, eyes, mycetoma, marginal spines.
Fig. 23. Leg.
Fig. 24. Antenna. Note spine on basal segment and the hairs on the hooked terminal segment.
Fig. 25. Dorsal view vasiform orifice, with adjacent spines, spiracles, dorsal pores.
Fig. 26. Ventral view mounted pupa showing breathing folds, legs, spine bases, segmentation, short cerci and marginal spines.
Fig. 27. Dorso-lateral view of late pupa to show box-like form, dorsal and marginal wax processes. The eye of the imago inside is seen through the wall.
Fig. 28. Dorsal view living pupa to show the marginal wax processes and cerci.
Fig. 29. Dorsal view showing tracheal system and spiracles. Note the small ramifications.
Fig. 30. Leg.
Fig. 31. Antenna. Note the pointed end.
Fig. 32. Dorsal view vasiform orifice and adjacent spines.
Fig. 33. Ventral view living pupa showing tubular entrances to breathing folds.
Fig. 34. Opening of posterior breathing fold. Note cerci and character of margin.
Fig. 35. Opening of thoracic fold. Note position of spiracle, and margin.
Fig. 36. Section through region of head of late pupa showing the two layers of chitin.
Fig. 37. Portion of partially emerged adult showing relation of adult leg to that of pupa.
Fig. 38. General outline of adult female. Only coxae of legs and bases of wings indicated. Note position of spiracles, antennae, eye, ocellus, wax plates, rostrum, ovipositors, position of vasiform orifice with hind gut; small prothoracic segment.
Fig. 39. Dorsal view of empty pupa case. Note T-shaped crack through which adult has emerged and the 11 pairs of long dorsal wax processes.
Fig. 40. Lateral view abdomen of female showing position of wax plates and the pleura of the segments.
Fig. 41. Ventral view of same.
Fig. 42. Proximal two-thirds of hind tibia. Note comb of spines on inner posterior side.
Fig. 43. Some of the meal. Note spiral form.
Fig. 44. Section through wax glands. Note character of gland cells and overlying chitin. (Section passes through the juncture of two segments.)
Fig. 45. Antenna. Note pseudosegmentation, sense organs, terminal point.
Fig. 46. Rostrum, showing invagination at end of first segment, and the imperfect joint in the second.
Fig. 47. Side view part of rostrum. Note groove and the toothed tip.
Fig. 48. Adult eye. Upper facets are smaller than the lower, with intervening short hairs.
Fig. 49. Side view of head. Note position of salivary pump and stylets, and the portion of rostral groove in the head.
Fig. 50. Side view of mouth-parts of first instar, to show loop of stylets inside body, and the rostrum.
Fig. 51. Claws and second tarsal segment. Note the small piece with which the claws and pulvillus articulate, and the long curved spine attached to the tarsal segment.

Fig. 52. Ventral view forewing. Note simple venation.
Fig. 53. Hind wing.
Fig. 54. Portion of wing margin.
Fig. 55. Lateral and slightly dorsal view of vasiform orifice. Note anus opening dorsal to the lingula, the row of hairs on the lingula and the depression at its tip.
Fig. 56. Vasiform orifice, with solidified honeydew between the lingula and operculum.

Abbreviations used in figures.

Anus	*A.*
Abdomen	*Ab.*
Antenna	*Ant.*
Cercus	*C.*
Claws	*Cl.*
Coxa	*Co.*
Dorsal spine	*D.*
Dorsal wax pore	*D.P.*
Dorsal surface	*D.S.*
Dorsal tracheal system	*D.T.*
Dorsal wax processes	*D.W.P.*
Eye	*E.*
Femur	*F.*
Future adult chitin	*F.A.C.*
Granules	*G.*
Hardened honeydew	*H.*
Leg	*L.*
Lower facets	*L.F.*
Lingula	*Li.*
Leaf tissue	*L.T.*
Meal	*M.*
Mandible	*Mand.*
Maxilla	*Max.*
Mesothorax	*Mes.*
Metathorax	*Met.*
Marginal wax processes	*M.P.*
Marginal spines	*M.S.*
Mycetoma	*My.*
Ocellus	*O.*
Operculum	*Op.*
Ovipositor	*Ov.*
Pleura	*P.*
Pupal chitin	*P.C.*
Posterior breathing fold	*P.F.*
Phloem	*Ph.*
Posterior marginal spine	*P.M.S.*
Prothorax	*Pr.*
Probable spiracle	*P.Sp.*
Pulvillus	*Pul.*
Pores for wax	*P.W.*
Rostrum	*R.*
Rostral groove	*R.G.*
Stylets	*S.*
Salivary pump	*Sal. P.*
Base of spine	*S.B.*
Spiracle	*Sp.*
Sensory pit	*S.P.*
Thorax	*T.*
Tarsus	*Tar.*
Thoracic breathing fold	*T.F.*
Tibia	*Ti*
Trochanter	*Tr.*
Upper facets	*U.*
Ventral spine	*V.*
Vacuole	*Vac.*
Vascular bundle	*V.B.*
Vasiform orifice	*V.O.*
Ventral surface	*V.S.*
Ventral tracheal system	*V.T.*
Wax plates	*W.*
Wax fringe	*W.F.*
Wax secreting cells	*W.S.*
Xylem	*X.*

INFECTION AND IMMUNITY STUDIES ON THE APPLE AND PEAR SCAB FUNGI (*VENTURIA INAEQUALIS* AND *V. PIRINA*).

By S. P. WILTSHIRE, B.Sc.

(With Plates XIX—XXII.)

The diseases of apple and pear caused by *Venturia inaequalis* (Cke.) and *V. pirina* (Aderh.) exhibit many interesting phenomena with regard to the resistance and susceptibility of varieties of the hosts. The investigations described in this paper were commenced with the object of discovering the method by which these fungi attack their hosts, in order finally to investigate the features concerning the question of relative immunity. Notwithstanding the rather considerable amount of work which has been done on these diseases—especially the extensive reports of the Agricultural Stations of the United States—little definite knowledge is available, either as to the minute details of infection or the power of resistance of attacked varieties. The recent paper of Wallace[1] contains an exhaustive review of previous work on these diseases: here therefore it is unnecessary to do more than make a brief reference to those points which concern the subjects dealt with in this paper.

The previous work which has been done with regard to the infection of *Venturia* is limited to comparatively few papers. Aderhold's work[2] on these fungi is by far the most important that has ever been published, and to him we are indebted for most of our knowledge of them. In his description of the germ tube he states that it broadens slightly at the point of entrance, which is usually directly over the junction of two or more epidermal cells, and bores directly through it. He mentions that the appressoria are frequently surrounded by a zone of mucilaginous material, but his figures show no signs of the collar which is described below, neither do they indicate the characteristic sub-cuticular mycelium.

[1] Wallace, *Scab Disease of Apples.* Cornell Univ. Agric. Exp. Station, Bull. 335.
[2] Aderhold, R., *Die Fusicladien unserer Obstbäume Land. Jahrb.* XXV, 875–914.

Fischer[1] states that *Venturia* cannot attack a completely uninjured fruit without previous injury to the epidermis. The attack is dependent on the weather, cold nights followed by warm days cause injury to the epidermis. Small cracks arise which can be seen with the aid of a lens, and he explains the conditions favouring infection, as due to the injuries of the cuticle brought about by them.

Voges[2] notes the presence of a "gelatinous envelope" round the appressoria which he suggests are functionary in attachment of the fungus.

Wallace (*loc. cit.*), by boiling up the leaf with caustic potash and thus releasing the cuticle, gathered that the germ tube of an ascospore bores its way directly through the cuticle and continues to grow between it and the epidermis. His figure, which, as far as the writer is aware, is the only one published of the entrance of the germ tube into the host, shows the hypha growing through a crack without the formation of an appressorium and without showing any difference between superficial and sub-cuticular mycelium.

For investigation of the problems of disease resistance connected with any pathological fungus, it is important first of all to determine the actual details of infection by the fungus. Having ascertained the facts of infection, knowledge as to the fate of the fungus after penetration into the tissues of the host is required. The work described in this paper deals primarily with those two subjects. In the case of the disease under investigation, a detailed study of the germination of the spores of *V. inaequalis* and *V. pirina*, the method of penetration into the hosts and the fate of the infecting hyphae was made. The methods of investigation adopted, the results and their bearing upon the above questions are described in turn below.

Methods. The germination of the conidia was examined by the method of drop cultures, conidia being obtained both from pure cultures of the fungi on artificial media and from affected leaves and fruits of apple and pear. The same sources served for a supply of conidia for the inoculation experiments. The inoculations were carried out on cut shoots and fruits under bell jars or on shoots which were enclosed in lamp chimneys held in position by clamps on the trees. The atmosphere was kept saturated with water vapour, and the inoculations were kept moist by means of addition of sterilised water from time to time.

[1] Fischer, *Pflanzenkrankheiten*, XIX, 432–434.

[2] Voges, *Zeitschr. Pflanzenkrankheiten* XX, 385–393.

These very artificial conditions were rendered necessary by the peculiar and special conditions under which the fungus infects the host and even under these, apparently the most favourable, infection is by no means always successful. There must remain, therefore, some slight possibility that the results obtained are simply pathological, but since the growth of the mature mycelium in nature is in many ways similar to that of the germ tube in infection, it is thought that this possibility is not very great.

Methods. Examination of inoculations was carried out by the ordinary method of serial sections, the fixatives mostly employed being chromacetic and acetic alcohol, with fuchsin and Licht Grün, and iron haematoxylin as stains. The course of infection was also watched from surface view from permanent preparations made as follows: inoculated portions were fixed in acetic alcohol for about half an hour, then washed and decolorised by absolute alcohol and finally mounted in Gilson's mounting medium, which is not so refractive as Canada balsam.

Germination. The conidia of *V. inaequalis* and *V. pirina* germinate readily in water, most of them showing a germ tube of considerable size after 24 hours, although some take a much longer time. The conidia are easily wetted, and their specific gravity is so heavy (or immediately becomes so on moistening) that on immersion in a drop of water they almost immediately sink to the bottom of it, where some change takes place, so that the conidium becomes attached to the surface on which it is resting. The comparative difficulty with which conidia about to germinate are washed from the slide on which they have rested suggests a definite attacking envelope, but although indications of an outer gelatinous layer have been seen under the microscope they are in all probability optical illusions, for similar indications are found with conidia of other fungi. In nature the germinating spore must after a short time experience desiccation and other changes due to the weather, but it is an extremely important point with regard to the beginnings of infection, that notwithstanding subsequent drying up germination can only be initiated after complete immersion in water for some time—a fact originally discovered by Aderhold, but perhaps hardly fully appreciated by the few more recent workers. It seems indeed rather curious that in an atmosphere saturated with aqueous vapour a spore will not germinate; and, as will be seen later, the correct appreciation of this fact, which has been repeatedly confirmed by the author, is of importance in understanding some of the characteristics exhibited by these fungi. Immersion in

water for a sufficiently long time having once initiated the first stages of germination, subsequent periods of desiccation seem to help rather than hinder the growth of the fungus. The appearance of the germ tube in the two species is characteristic, for in *V. inaequalis* it is rather a continuation of the spore, being formed by the more pointed end growing out as the germ tube; whilst in the case of the *V. pirina* it is sharply defined, arising as a lateral growth near to one end of the spore.

In a hanging drop, the germ tube continues to grow out as a long thin colourless hypha, but on the leaf desiccation soon brings the germ tube in contact with the cuticle and this immediately brings about the formation of an appressorium, the stimulus of contact, shown by Aderhold, causing the germ tube to swell up and at the same time to be closely applied to the cuticle. Some substance is excreted round it so that a flange-like structure is formed round the end of the germ tube, fixing it firmly to the cuticle (see Fig. 1). The changes in shape of the fungal hypha and the exact method by which the flange was formed could not be definitely followed, but the latter seemed to arise as an excretion from the fungal hyphae, no part of the cuticle being involved. At first the flat portion of the flange, which is usually very thin, especially at the edges is colourless; but it soon becomes brown and can readily be seen under the microscope. These "collars" or flanges are much more prominent in some cases than in others, apparently depending upon the state of health of the spore and the conditions of growth of the fungus. The nucleus can usually be seen to be very evident in the appressoria denoting probably great metabolic activity in this region. The formation of the appressorium is not limited to the germ tube, as the tip of any growing hypha may respond to the stimulus, although there is no evidence that the mature mycelium is capable of doing so. If after the formation of the appressorium, the spore is still kept immersed in water, the appressorium begins to put out a hypha from its upper surface, and later its appearance may suggest that it was a lateral outgrowth from the mature hypha. The germ tube generally forms only one appressorium, normally at a short distance from the spore, but sometimes it branches and even develops a short superficial mycelium producing five or six appressoria.

Aderhold and many other workers have noted that the germ tubes frequently swell up into the appressoria over the junctions of the epidermal cells, especially where three or more cells meet. Very careful examination of inoculations in superficial view has been made

and there is apparently a tendency for appressoria to be formed at the place recorded. Further details on this point are referred to later.

Penetration. A point of great importance in infection is that only young leaves or fruits are capable of being infected. This fact has been firmly established both by observations in the field and by direct experiments. In July the ordinary summer pruning was carried out in the nursery at Long Ashton, and at the end of September a good number of young shoots had developed from the dormant buds which had thus been roused into activity. On the susceptible varieties this young foliage was heavily infected while the mature foliage showed no recent infection. Aderhold has noted the liability of the young organs to be attacked, but recently Wallace cited instances where *V. inaequalis* spread rapidly amongst apples in storage. Whilst under certain conditions therefore mature organs may be successfully infected, it appeared certain in the case of the trees under inspection at Long Ashton that little late infection took place.

To avoid possible misunderstanding it should be explained that the use of the term "infection" in the previous paragraph includes not merely the penetration of the fungus into the tissues of the host, but also its development afterwards to such a degree that the infected area carrying a crop of conidia can be seen with the naked eye. It is possible that penetration may occur on older foliage and fruit: but if so, the fungus appears unable to grow to any appreciable extent in the tissues of the host.

In view of the above it is clear that normal penetration of the cuticle and further growth of the fungus must be followed on very young leaves. When the appressorium is firmly established a growth of the hypha into the cuticle takes place, beginning as a small bulge from the centre of the attached disc (Fig. 5 and compare Figs. 11, 12). The hypha usually grows directly into the cuticle at right angles to the surface of the leaf, but occasionally it is inclined obliquely (Figs. 6 and 7). As it penetrates inwards it very often becomes enlarged, possibly in order to secure the further attachment of infecting hypha. The cuticle being extremely thin in the case of young leaves, the wall of the epidermal cells is reached almost at once by the hypha which then begins to grow between the epidermal wall and this cuticle, forming a plate-like mycelium of very characteristic appearance (Figs. 2 and 3). The cells at first are very thin and the plate is on y one cell in thickness, but soon the fungus gets food from its host and the hyphae begin to

increase in size and divide so as to form a pad of cells, sometimes pushing the cuticle outwards, sometimes crushing the epidermal wall inwards. This subcuticular mycelium continues to grow out in all directions, sometimes long arms of the mycelium projecting from the original point of infection. It may at first consist of one long hypha which will divide to form the mycelium afterwards, but usually the mycelium spreads in a plate-like manner. The cells always remain hyaline and do not become brown as in the ordinary superficial mycelium. The growth of the mycelium seems to be hindered to some extent at the junctures of the epidermal cells, for it is not uncommon to find one epidermal cell covered with mycelium and most of the neighbouring ones quite free (Fig. 4).

The exterior walls of the epidermal cells are usually convex, and projecting portions of the cuticle fit in between adjacent cells. In passing from above one epidermal cell to the next the fungus almost always keeps between the cuticle and the epidermal walls without dissolving away the former to any great extent. Therefore it seems probable that for mechanical reasons it might be difficult for the fungus to pass over these junctures, and especially would this difficulty be felt by the older mycelium growing out laterally from the original invading strand rather than by the young hyphae meeting the juncture at right angles. The attack of one of these scab fungi at first has no apparent influence on the epidermal cells, the nuclei remaining in their normal position which is near the lower walls; but later various changes may take place, the cell contents being frequently conglomerated into a granular gumming substance, especially with artificial infections made in bell jars. A substance which gives the red colour characteristic of wound gum, with phloroglucin and hydrochloric acid, has also been found excreted into the intercellular spaces of the leaf of the pear when its lower surface is attacked. The final effect usually produced on the affected leaf is the extension of the palisade layers into a kind of phellogen round the scabbed area, this development frequently causing the leaf to be somewhat curled.

Sometimes in the thickened region of the cuticle above the vertical walls of the epidermal cells there appears a structure resembling a hypha cut in transverse section and a similar structure can occasionally be seen strictly following the junctions of the cells, if an inoculation be examined in superficial view (Fig. 25). It does not seem that the infecting hypha always behaves in this manner before it enters upon its true subcuticular position: but when it is remembered that the

appressoria appear to be formed over the same points, it seems to afford some significance, the importance of which is discussed below.

The subcuticular mycelium having been formed in the leaf, the uppermost cells of the stroma begin to enlarge, and push out the cuticle until they burst it open and form the conidiophores from which conidia begin at once to be cut off.

The method by which the conidiophore passes through the thick cuticle on the fruit may be of interest as affording a comparison with the method of entrance. There are two ways in which it does this: (*a*) by eating away the cuticle in exactly similar manner to which it infects, (*b*) by growth of the subcuticular stroma at right angles to the surface so that the cuticle is burst off. The fungus lives typically between the cuticle and the outer wall of the epidermal cells, but on the fruit it does not simply force its way between the layers. It also partially eats away the cuticle as it is invariably seen that this layer is thinner where it covers the mycelium. Sometimes at the edge of the scabbed patch the actual hypha can be seen completely embedded in the cuticle. Hence there is absolutely no doubt that there is some cuticle dissolving excretion exuded by the fungus in its passage through this layer.

It is not purposed to continue a description of the life-history further, since in a resistant variety the fungus never reaches a stage beyond that already described. In the following account of the resistance and susceptibility of the hosts, reference will be made again to various stages in inoculation of other portions of the plant; but the above account is typical of what happens in the normal infection of a young leaf.

The Question of Immunity.

Perhaps no other important disease exhibits such irregular behaviour as these fungi as regards their immunity. For example, it is well known that one variety may be heavily attacked one year and remain almost immune the next, although the organism may be quite near. Wallace says "it is found that certain varieties may be resistant in one year and susceptible in another year under conditions which for average varieties are as favourable to the disease in the one case as in the other." Salmon reports that at the Wye College Cox's orange pippin had almost every shoot attacked by *V. inaequalis* but at this station extremely little of this fungus was found on the variety at all during 1914. It is considered that the suggestion which at once occurs, viz. that this

characteristic behaviour of the disease may be due to variations in the climatic conditions at the time when the hosts are in most susceptible condition, is not a sufficient explanation, and Wallace thinks that the fungus itself is adapting itself to life on the "resistant" hosts. Again, too, there is great variation in the parts of the host attacked. Sometimes it is especially the stem, sometimes the leaves, sometimes the fruit. Again, the part of the host especially attacked, whether leaf, stem, or fruit, varies considerably under conditions of which we know little. The absence of adequately definite facts makes it at present unprofitable to formulate hypotheses to account for these phenomena, but on fuller knowledge it seems probable that much of the accessory factors connected with the immunity of these fungi might be explained. In the following instance some such explanation is attempted. It is well known that the pear fungus appears on the fruit first and on the foliage afterwards, whilst in the case of the apple the conditions are reversed. Now it seems likely that the very thick woolly coating of hairs on the young fruit of the apple very efficiently protect it from becoming wetted and consequently infected. Later when this covering disappears infection very readily takes place. There are many fungi in common with *Venturia* which attack their hosts in a more or less localized portion, and it is usually the young organs which are most susceptible. There seems to be a definite correlation between the age of the leaf and its powers of resistance. We might point to a parallel amongst animals in the everyday fact that the young are more susceptible to certain diseases than adults. In the case of plants it is not known whether this increased resistance accompanying age is due to the better protection of the host against attacks of fungi, such as might be afforded by the thickening of the cuticle, or whether the limiting factor is intimately associated with the life of the living cell, and the fungus is killed after penetrating the cuticle. Definite experiments were therefore made to find out what happens when spores attack the mature leaves of various varieties of some of which the young organs are susceptible. For this purpose the mycelium from a pure culture was used for inoculations, in order that the fungus might have a larger reserve of food material to sustain itself in the attack than that contained in the spore. In the case of the pear William's Bon Chretien, a susceptible variety, the fungus developed normally up to the stage of the formation of the appressorium and the issuing of the hypha from its underside into the cuticle. Instead, however, of the infection hypha penetrating completely through the cuticle, and developing

immediately a subcuticular mycelium, it showed a great tendency to grow out horizontally into the cuticle (Fig. 21), which on the older leaves is of sufficient thickness to allow this. There seems some preference of the fungus for the outer portion of the cuticle, rather than that adjacent to the epidermis, but finger-like processes, especially from the underside, are given off as branches from the main hyphae. Sometimes these processes reach the epidermal cell-wall and the formation of a subcuticular mycelium takes place: but it was never observed to reach any advanced stage in development, always remaining very simple (Fig. 22). After a varying interval of time the cells of the fungus die off, their contents becoming converted into dark brownish spherical granules. From very many inoculations on mature leaves, both in bell jars and on the trees in plantations, no conidia have ever been produced. Even when the mature leaves of a resistant variety are inoculated, the same course of events is followed. Fig. 20 shows the dead hyphae of *V. pirina* in the cuticle of the Catillac pear, a resistant variety which was very heavily inoculated with pure mycelium. It will be noticed also that the epidermal cells show the beginnings of the formation of a phellogen, which in the normal progress of the disease is developed after the attack has developed for some time, and which has been reported by Voges.

In the inoculation of the mature fruit much the same thing happens, although the cuticle here being much thicker it is much easier to follow what takes place. The infection hypha from the appressorium grows directly into the cuticle (Figs. 11, 12 and 13) and then at its innermost end swells slightly until it becomes almost spherical (Fig. 14). Growth can now proceed in all directions, but much more easily in a plane parallel with the surface of the fruit (Fig. 15). Occasionally, however, it penetrates slowly, following its original course (Figs. 16 and 17). The cuticle is apparently laid down in layers, for with all kinds of stains the innermost layers almost invariably take on a deeper colour than the outer ones, and distinct striations can nearly always be seen, especially where it covers the juncture of neighbouring cells of the epidermis. The direction of growth of the hyphae now seems to follow these striations sometimes to an astonishing length, suggesting perhaps that the physical character of the cuticle is an important factor (Figs. 18 and 19). It has been found extremely difficult to infect successfully the mature fruit (using the term "infect" as explained above); and although this is reported to occur under certain conditions the ordinary course of events seems to be for the fungus to die off in

exactly similar manner as when attacking mature leaves as above described.

Although great differences occur between the attacks on certain varieties in successive seasons, yet there are some varieties which always remain highly resistant, if not completely immune, to this disease. It was therefore interesting to determine the fate of the fungus on the young leaves of resistant varieties. For this, Bramley's Seedling and Newton Wonder apples were selected as resistant varieties for *V. inaequalis*, with Cap of Liberty, a well-known cider apple, as the susceptible variety for comparison; also the pear William's Bon Chretien, a variety susceptible to *V. pirina*, was infected, being regarded as resistant to *V. inaequalis*. All were inoculated with conidia of *V. inaequalis* obtained from the leaves of the "Cap of Liberty," and the results were very similar. Appressoria were formed as usual, infection hyphae sent out into the cuticle, but in resistant varieties the adverse effect of the host was quickly felt (Figs. 23, 24, 25) although sometimes the fungus succeeded in penetrating completely through the cuticle and forming a subcuticular pad. This usually appeared quite unhealthy, the cells being smaller and narrower. The cuticle being so thin no horizontal development of the mycelium in it could be detected except in a few cases. Inoculations of *V. pirina* also were made on the fruit of the apple, King of the Pippins, which is susceptible to *V. inaequalis*, but in no case was the infecting hyphae seen not to have penetrated into the cuticle. The apple fungus easily penetrated into the cuticle of the pear and the pear fungus that of the apple. On Bramley's Seedling the fungus exhibited a preference for that portion of the cuticle above the junctures of the epidermal cells already referred to (Fig. 25). Eventually in the resistant types the mycelium ceased to grow and practically died off. With the susceptible types on the other hand a healthy subcuticular mycelium was quickly formed and developed in the normal way described above until the production of conidia resulted.

General Considerations.

The problems of immunity are particularly difficult because in dealing with them we have to deal with fundamental life processes which do not lend themselves to experimental conditions. All the work which has been done towards the elucidation of the limiting factors of immunity has been done with obligate parasites such as the Mildews and the Rusts, but unfortuuately none of these fungi will

grow apart from the host. The facultative parasite affords a line of attack of this difficult problem, for after a determination has been made of what can be seen to happen to the fungus within the host of both susceptible and immune varieties it might be possible to submit the fungus to culture apart from the host and in media which may have been directly derived from the host. If we are to attempt to enquire whether the non-infection of an immune form is due to a toxin, or anything of a similar nature, we must follow some such line as this. *Venturia* is quite a unique fungus in its normal habitat between the cuticle and the host: and although the process of infection and subsequent manner of growth in the host may be peculiar to itself, yet it may be well to discuss it in relation to what is known of other fungi. It is not proposed to review the literature on this question in any detail, since these results would not warrant such an exposition, but a brief outline of the principal work has been done, especially that associated with *Venturia* may be given.

Büsgen[1] found with *Venturia* that the appressoria are formed frequently over the epidermal walls perpendicular to the surface, and endeavoured to show that diffusion of some substance takes place at this place and which acts chemotropically on the germ tube.

Aderhold (*loc. cit.*) holds that no particular chemotactic stimulus is necessary, but that there is simply a strong diffusion of the ingredients of the cell contents; this, however, he was not able to ascertain in demonstrable quantities in living tissues. He held that at the junctures of the epidermal cells the external cell-wall must have other properties than those of the flat surfaces of the remainder of the external walls. He records experiments which are not very conclusive but from which he gathers that the pectates (especially potassium pectate) act chemotropically on the fungus and suggests that the middle lamella may so act in nature.

In addition there is the work of Myoshi, Nordhausen, Fulton and others on general questions of chemotropism, but, so far as we know, no other paper discusses the question in relation to *Venturia*.

The question of how the infecting hyphae pass through the cuticle must take into consideration the nature of the cuticle itself. The work which has already been done does not give much information, being chiefly concerned with the distinction of cuticle from cork, whether cuticle contains any cellulose and similar chemical problems.

[1] Büsgen, M., *Ueber einige Eigenschaften der keimlinge parasitische Pilze. Bot. Zeit.* 1893, p 53.

The cuticle is a protective covering layer to all young parts of plants and hence must be capable of very rapid extension. It is not known how such growth takes place, whether the outer walls of the epidermal cells become gradually converted into cutin or whether the cutin itself is a secretion of the cell. The cuticle, however, must not be regarded as being a simple homogeneous body. Von Höhnel[1] in 1878 stated that the external layers of the cuticle are free from cellulose, whereas those layers bordering on the external walls of the epidermal cells represent cellulose saturated with cutin. More recently Géneau de Lamartiere in 1906 has seen fit to distinguish the former as the epicuticle. With all the common stains it is found that the portion of the cuticle next the epidermal cells is coloured more deeply than the rest of the cuticle, particularly in the projections which fit between the adjacent epidermal cells; and moreover, the general staining of the cuticle suggests that it has been formed in layers. The outer layers, being continually exposed to complete desiccation, must be under greatly different conditions from those next to the epidermis. Hence it appears probable that the cuticle has a structure of its own: and this may be an important factor in the penetration of the infection hyphae through it.

The permeability of the cuticle is of interest, as regards the chemotropic attraction which certain substances have on fungal hyphae. That substances can diffuse through the cuticle in some cases cannot be doubted, since the copper of Bordeaux mixture slowly passes into leaves of certain plants, such as potatoes, which have been sprayed with it (Barker and Gimingham[2]). Whether any substance which may render the copper in such cases soluble diffuses out through the cuticle is not known, and the position is similar with regard to the diffusion of substances possibly chemotropic to fungal hyphae. Nevertheless it must always be remembered that such a thing may happen in nature.

The observation that the appressoria are formed frequently over the juncture of epidermal cells, seems to be justified from a careful examination of inoculations in surface view. But it is by no means the case that they are formed only in these positions. On examining 300 appressoria, 26 % were found to be over the centre of the cells and between 14–19 % did not touch the junctures although they were perhaps near them. If we take into account the relative sizes of the appressoria and the cells, this result may not appear to be particularly unexpected. The area within which an appressorium if it fell would

[1] See Czapek, *Biochemie der Pflanzen*, p. 702, 1912 Ed.

[2] Barker and Gimingham, *Ann. Applied Biology*, Vol. I. p. 19.

touch the juncture of the epidermal cells would be bounded by a line, the breadth of the appressorium within the edge of the cell; and taking the relative sizes of the diameters of the cells and appressoria roughly as 6 : 1, we should find this area would be $\frac{5}{4}$ that remaining. Hence we might expect the appressoria to touch the junctures of the epidermal cells more often than not. On the other hand, however, other fungi as well as bacteria are said to show a similar liking for that part of the cuticle above the junctions of the walls. The elaborate paper of Fulton, in which he calls in question the whole of the work done on chemotropic attraction of fungal hyphae, makes us suspicious of accepting altogether the works of earlier investigators and it becomes more and more evident that a further study of chemotropism is necessary for the progress of enquiry into the question of the attack of parasitic fungi. It is not yet established whether chemotropism does exist at all; and not until we know, not only whether it exists but also whether it plays any part in infection, can we hope to attempt to solve the question why the fungal hypha enters the host.

If some chemotropic substance does influence the direction of growth of the germ tube, it must either be the exterior layers of the cuticle or something formed interior to them and then excreted. There is no reason to suppose that the exterior of that portion of the cuticle covering the perpendicular epidermal walls has peculiar properties. Nordhausen has suggested that the mechanical checking which the germ tube undergoes on crossing a groove or the collection of water in it may account for the predilection of the appressoria for this position, yet the behaviour of appressoria is quite similar on varieties like Port and William's Bon Chretien which have no grooves (see Figs. 26, 27 and compare Fig. 28). That the cuticle which covers the junctures of the epidermal cells is, however, different from the remaining is shown by the different staining properties it possesses; this fact, taken in conjunction with the occasional occurrence of hyphae embedded there, suggests rather pointedly that this may be a substance chemotropically attractive to the germ tube. At the best, however, *this* chemotropism can be only an accessory factor in infection since hyphae can penetrate the cuticle quite well in the middle of the epidermal cell-walls.

The growth of the infection hyphae from the appressoria through the cuticle itself is interesting in connection with the part played by chemotropism. If the hypha entered solely because attracted by the substances in the epidermal cells or cell-walls of the host, we should suspect that it would bore directly through the cuticle to reach the

subcuticular position. But although the cuticle of organs susceptible to attack is very often so thin as to prevent the horizontal growth of the infection hyphae in it, yet occasionally one finds stages as represented in the Figs. 6 and 7. These figures suggest that there is no guiding influence towards the epidermis, but that the fungus simply eats its way slowly through the cuticle until it arrives between the cuticle and epidermal cell-wall. With mature organs of both susceptible and resistant varieties where the cuticle is thicker, we have still more interesting cases. How can the long horizontal growth of the infection hyphae in the cuticle (a very frequent occurrence) be explained? Does it not rather suggest in place of an attracting substance the presence of something which is repulsive to the invading hypha? The physical layering of the cuticle may have something to do with the direction of growth, but this horizontal habit is not confined to fruits but is also exhibited in mature leaves, where the layering of the cuticle is not nearly so evident on staining. Of course, the tendency is most clearly developed in resistant organs because the young susceptible parts of plants have very thin cuticles, but that it should occur at all strongly negatives the view of the germ tube being attracted by the cell sap of the host. The conclusion seems unavoidable that the fungus infects *in spite of* the host, and that chemotropism if it acts at all must play a very insignificant part in the process.

It has been shown that immunity does not depend on freedom from the initial attack, any more than in the case of the rusts; immunity there depends upon the non-entry of the infection tube into the host. What the limiting factor in immunity is, we can only speculate—it may be simple starvation of the fungus, as suggested by the gradual reduction of growth, or it may possibly be the formation of some toxic substance. With such possibilities existing it might be well to mention here some experiments which were made on the growth of the conidia of *V. inaequalis* in the expressed sap of the young leaves of certain varieties of apples. Young leaves of King of the Pippins (susceptible) and Bramley's Seedling (resistant) were pounded in a mortar and the sap then squeezed out of them. Conidia were then sown in the sap and hanging drop preparations made which, although by no means free from bacteria and yeasts, remained sufficiently pure for the one or two days necessary for the experiment. Control drops were set up with water instead of the sap medium. In all cases the growth of the conidia in the sap was very much slower than in water and a much larger percentage did not germinate. On diluting the sap, the conditions

of germination were gradually improved until in media of which the ratio of sap to water was 1 : 10 no difference from the water controls could be observed. A few further experiments were made with Newton Wonder (resistant) and Cap of Liberty (susceptible) which as far as they went coincided with the results given above. In these sets of preparations the conidia appeared to grow better in the sap of the susceptible varieties than in that of the resistant kinds: but the approach of winter rendered it impossible to carry this work any further for the time being. The little which has already been done seems to support the view obtained from the study of microscopical preparations that the host is antagonistic to rather than attractive towards the parasite.

The facts which are recorded in this paper are therefore considered to suggest that the appressorium, being formed as the result of mechanical stimulus as shown by Aderhold, penetrates into the cuticle, feeding on it as it goes and finally reaching its normal habitat between the cuticle and epidermis where it flourishes, if the attacked variety is susceptible.

Immunity is shown not to depend on the protection of the cuticle and indications are recorded which suggest the probability of the cell sap of the host being in all cases antagonistic to the fungus.

In conclusion I should like to express my deepest thanks to Professor B. T. P. Barker, M.A., at whose suggestion the work was begun, and who throughout has rendered invaluable aid by helpful criticism and advice. I am also indebted to him for facilities for working at the Agricultural and Horticultural Research Station of the University of Bristol.

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Fig. 2. Spore of *Venturia pirina* germinating on leaf of pear Louise Bonne de Jersey. ×1600.

Fig. 3. Same showing later stage. ×1600.

Fig. 4. Mycelium of *Venturia inaequalis* in leaf of apple Cap of Liberty, surface view showing delimitation of mycelium juncture of the epidermal walls. ×1600.

Fig. 5. Appressorium of *Venturia inaequalis* on the leaf. ×1600.

Fig. 6. Entrance of infection hypha into the cuticle on leaf of apple Cap of Liberty. ×1600.

Fig. 7. Same. ×1600.

Fig. 8. Same, later stage. ×1600.

Fig. 9. Same. ×1600.

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Figs. 18 and 19. Growth of mycelium of *Venturia inaequalis* in the cuticle of apple King of the Pippins, showing how it roughly follows the layering of the cuticle. × 1600.

Fig. 20. *Venturia pirina* on mature leaves of pear Catillac (resistant). × 1600.

Fig. 21. *Venturia pirina* on mature leaves of pear William's Bon Chretien (susceptible in young leaves). × 1600.

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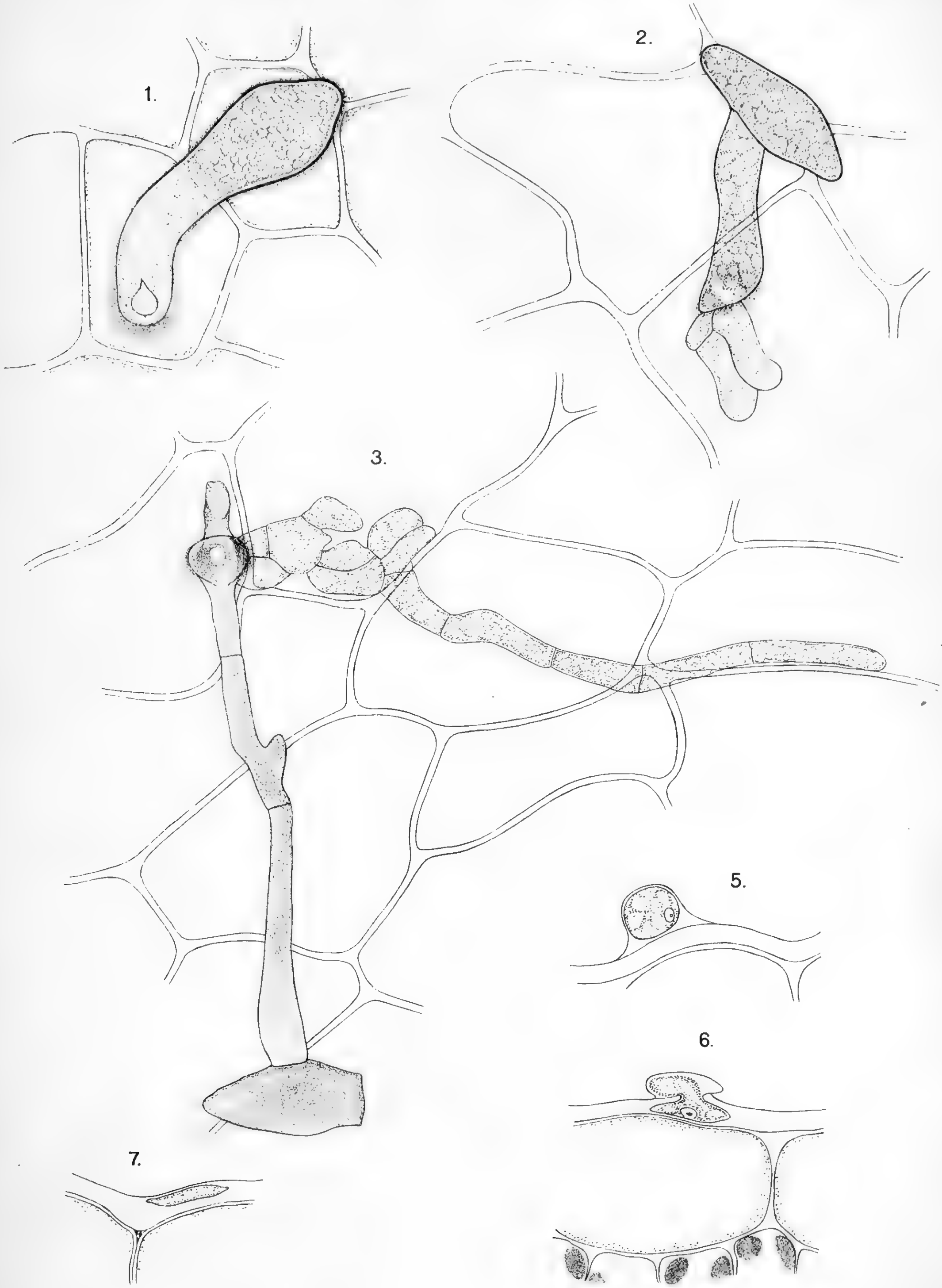
Figs. 23, 24, 25. *Venturia inaequalis* on the young leaves of apple Bramley's Seedling (resistant). × 2050.

Fig. 26. Cuticle of pear William's Bon Chretien.

Fig. 27. Cuticle of pear Port.

Fig. 28. Cuticle of pear Catillac.



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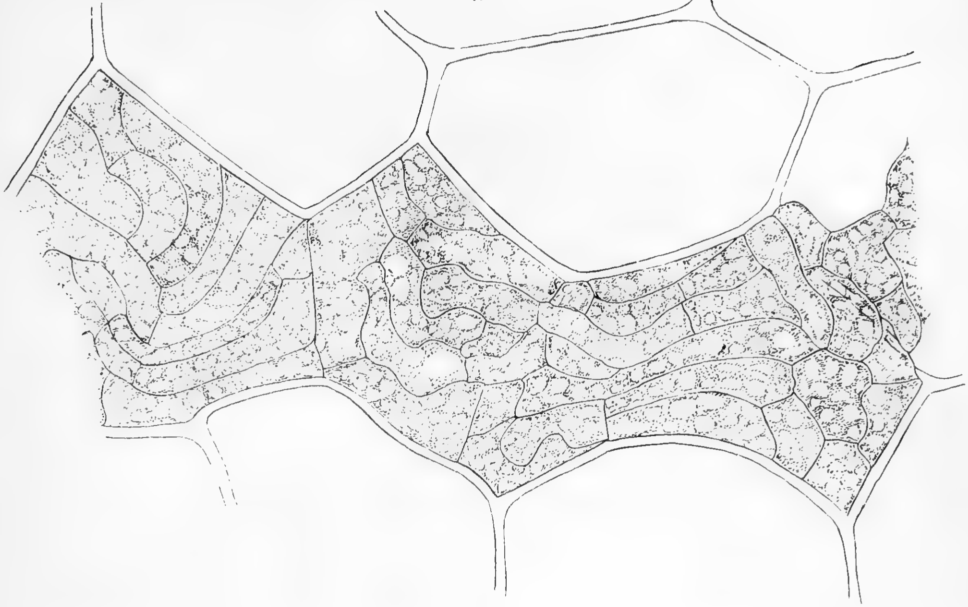

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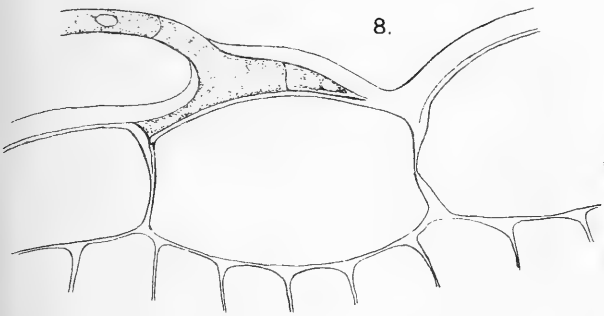

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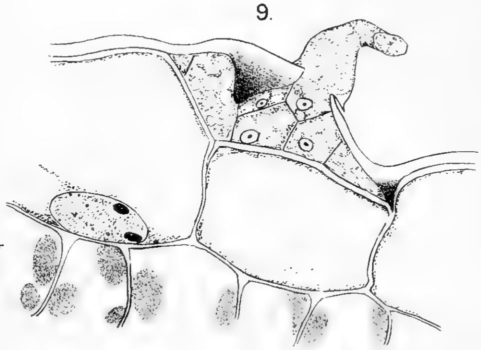

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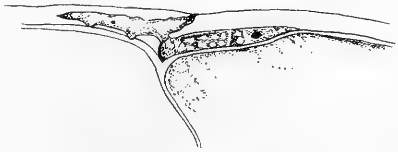

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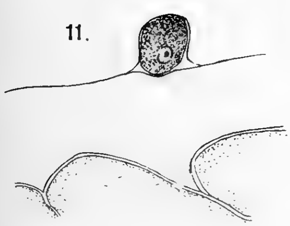

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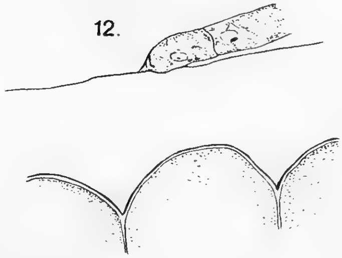

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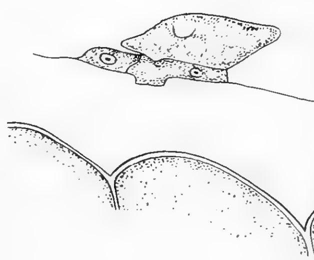

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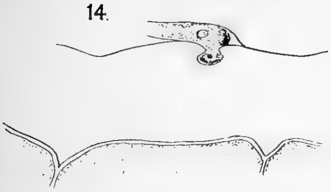

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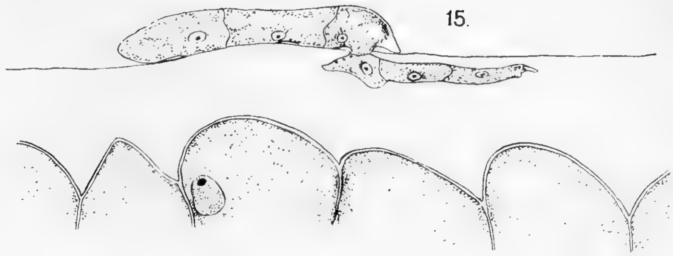

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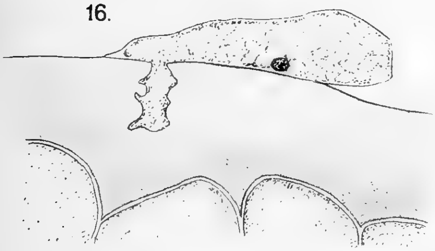

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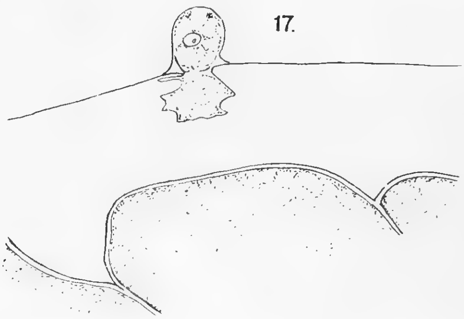

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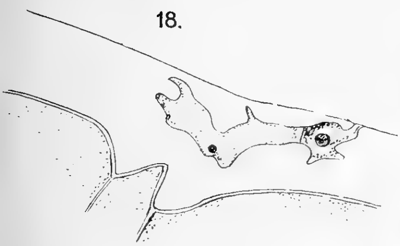

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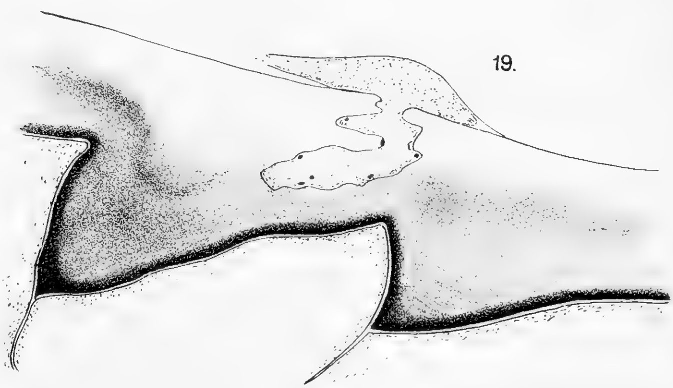

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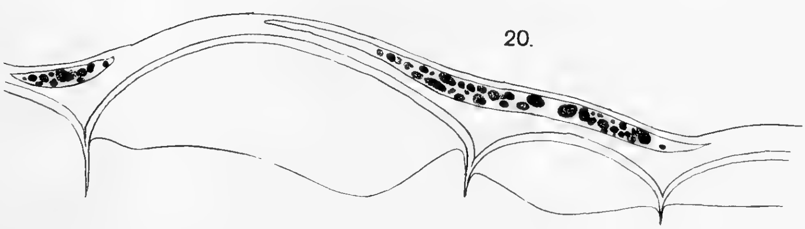

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PLATE XXII.

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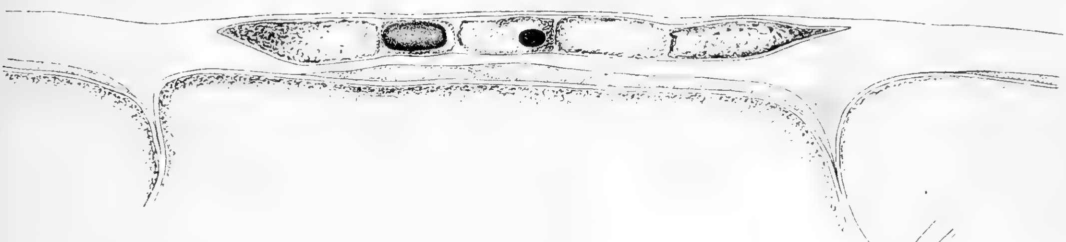

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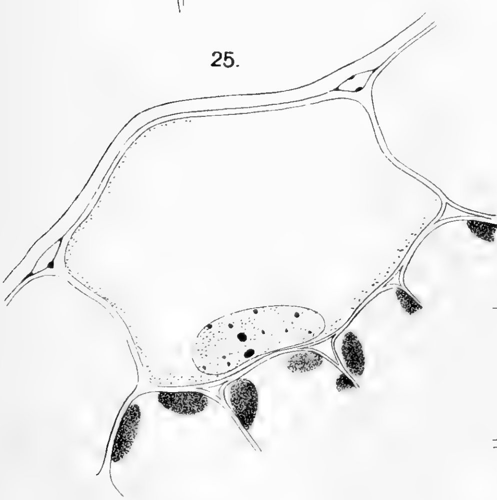

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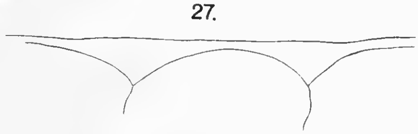

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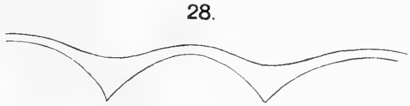

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WINTER COVER WASHES.

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WINTER cover washes or more properly late spring cover washes were first tried on the large scale by Mr Howard Chapman of Kent. He found by experience that a lime wash applied as late as possible before the buds burst in spring produced a very decided lessening of Psylla attack and consequent increase of crop. Cover washes have also certain other subsidiary but very real advantages:

(1) They can be applied when labour is easily obtainable. A summer wash has to be put on at the end of April, nearly two months later, when labour is urgently needed for other operations.

(2) They tend to keep the bark clean.

(3) They add a small amount of lime or chalk to the soil.

Since its introduction lime wash has been tried by many growers, some of whom have become enthusiastic advocates of it, while in the hands of others it has produced no apparent good. It seemed therefore desirable to make some investigation into its action. Two hypotheses were current to account for its good action, since undoubtedly it has had good action in some places and under some conditions. The first suggested that its action was due to the causticity of the hot lime, which had some effect on the protoplasm inside the egg or at any rate so influenced the egg shell as to render the ovum fatally susceptible to outside conditions. The second supposed that the lime covering had no direct action but only an indirect mechanical one, effectually sealing in the eggs and preventing the hatching of the enclosed larva. It was obvious from the outset that the first explanation was unlikely. When one considers that the chitin of insect eggs can resist being boiled in strong caustic soda, it is not likely that the feebly caustic lime would affect it. The second thus appeared a more

likely hypothesis. Working on this it is at once apparent that to make such a wash most efficient certain conditions must be fulfilled. These are:

(1) It must give a thick covering.

(2) It must resist all external conditions causing lessening of the coat when once on the tree, *i.e.* it should not flake when dry or wash away when wetted by rain.

(3) It should be applied as late in the spring as possible.

(4) The materials should be reasonably cheap and easy to get.

(5) It should be easily made.

All the experiments hereafter described had to be done in the dead season, beginning in the autumn of the year and ending in the late spring of the following year when the buds had begun to burst. They may be grouped more or less in a chronological order in order to retain the sequence of ideas.

Season 1912–13.

Laboratory experiments.

Experiments were begun to find some mixture that was more resistant to erosion than lime alone. In the first trials twigs were dipped into the various mixtures and allowed to dry in the laboratory.

It was found, however, that this method gave unsatisfactory results, as the twigs themselves soon dried and contracted away from the coating of material applied to them, so that the best wash under these conditions soon began to flake. On the living twig this is not so. In all subsequent laboratory experiments the washes were poured upon ordinary 3×1 microscope slides and allowed to drain as they dried. The smooth surface of the slide was an additional guarantee of good sticking qualities. In practice, in the field, twigs are always slightly rough so that any wash adhering well to glass slides should do so quite as well when applied to a tree. Plain lime wash at the rate of 2 lbs. to the gallon of water was used as control. It having been frequently stated that the addition of waterglass or sodium silicate improved the adhesiveness, this was first tried. All quantities are calculated in pounds of material to pounds of water or in grains per c.c.

The following (with the salt left out) recommended by Theobald

Lime	Waterglass	Water
20	1	100

produced no improvement; if anything it was inferior to plain lime wash. This is not surprising as calcium silicate, which is formed by the action of lime on sodium silicate, is a hard brittle body and not likely to give adhesiveness in the quantity used above. Greater strengths would prove too expensive. The addition of salt, according to the following formula:

Lime	Salt	Water
20	2	100

gave the same negative result.

It having been brought to the author's notice that tallow was used by many firms who did outside lime washing, the following was tried, the tallow being added as the lime was slaking:

Lime	Tallow	Water
50	2	250

This formula proved of doubtful value.

Field experiments.

The lime and tallow wash was tried at five different centres in counties within the advisory area of the Bristol University Research Station, the lime and salt at eight and the whiting and size at three. Control experiments were also done at Long Ashton.

The whiting and size formula gave very good results but as a practical wash it is far too expensive.

Lime and tallow showed no superiority over lime and salt. Sometimes one gave a better result and sometimes the other, and it was clear that good sticking power depended more on the freshness of the lime than on any other factor.

SEASON 1913–14.

Laboratory experiments.

The whiting and size wash, though giving a good coat, proved far too expensive. Less quantities of size than that used above gave too thin a coating.

Accordingly an attempt was made to obtain a cheaper form of glue. After some trial one was obtained at about 4*d.* a lb. in hundredweight quantities. This brought down the cost to about 5*d.* a gallon which was still prohibitive. It was found that smaller quantities of glue

gave sufficient adhesive power but not sufficient covering power. Starch paste was therefore tried to remedy this according to the formula:

Whiting	Glue	Starch	Water
8	$\frac{1}{8}$	$\frac{1}{4}$	10

This gave a thick and fairly firm coat. Less starch gave too thin and loose a coat while more glue became too expensive. In order to get a cheap form of starch, ordinary flour was used after being converted by hot water into paste.

Three formulas were made up with varying amounts of flour and glue. The results and costs are included in the table below:

No.	Whiting	Glue	Flour	Water	Result when dry	Cost per gallon
(1)	8	$\frac{1}{8}$	$\frac{1}{4}$	10	Fair coat	$2\frac{1}{12}d.$
(2)	8	$\frac{1}{4}$	$\frac{1}{4}$	10	Better than No. (1) ..	$2\frac{7}{12}d.$
(3)	8	$\frac{1}{4}$	$\frac{1}{2}$	10	Still better coat ..	$2\frac{10}{12}d.$

The price of all these is rather high and they have besides other disadvantages.

When such a coating is exposed to the action of water it quickly gets washed away owing to the solubility of the glue, but if a small quantity of potassium dichromate is added the glue is rendered insoluble on exposure to light. This action depends on the gelatine of the glue which, mixed with dichromate and exposed to light, becomes insoluble.

The following formulae were then tried:

Whiting	Glue	Flour	Pot. dichromate	Water
8	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	10
8	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{8}$	10
8	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{16}$	10
8	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{32}$	10

In all cases the addition of the dichromate caused a great thinning in the consistency of the liquid and a poor coat resulted. On trying starch again according to the formulae:

Whiting	Glue	Starch	Dichromate	Water
8	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{32}$	10
8	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{64}$	10

good covering power and adhesiveness were obtained in both cases. It was necessary therefore to obtain a cheap form of starch and this was found in "Farina," a potato flour which cost about 2*d.* a pound when bought by the hundredweight. Accordingly the following two mixtures were tried:

No.	Whiting	Glue	Farina	Water
(1)	8	$\frac{1}{8}$	$\frac{1}{4}$	10
(2)	8	$\frac{1}{8}$	$\frac{1}{8}$	10

Both gave good coverings and were more satisfactory than those made with ordinary starch.

With the idea of incorporating a fungicide Bordeaux mixture was added, but it caused great thinning of the liquid.

The same result was obtained when copper sulphate was added. The addition of flowers of sulphur, with the same end in view, though it caused no thinning was unsatisfactory as the dried coat showed great tendency to flake.

The cost of No. (2) of the above table is *2d.* a gallon of which the whiting costs $1\frac{1}{4}d.$, the glue $\frac{1}{2}d.$ and the farina $\frac{1}{4}d.$

Owing to the expense of the whiting, due chiefly to the large quantities necessary to produce a thick coat, lime was again tried as the covering material. The following mixtures were tried with the results included in the table:

Lime	Glue	Farina	Water	Result
2	—	—	10	Poor covering
2	$\frac{1}{2}$	—	10	Poor covering
2	$\frac{1}{8}$	$\frac{1}{8}$	10	Very good but flocculent and inclined to flake
2	—	$\frac{1}{4}$	10	Too thick but not firm enough
2	—	$\frac{1}{8}$	10	As thick but not coherent and flaking when dry

In order to stop this flaking a mixture of lime and whiting was tried with the idea that the different sized particles thus introduced might interlock and so prevent the flaking:

Lime	Whiting	Glue	Farina	Water
14	7	1	1	80

This mixture, though it appeared not to flake at first after a few days did so. It was suggested that the addition of cressyllic acid which is supposedly used in some distempers might give good adherence. 1, 2 and 5 per cent. added to the ordinary lime wash, however, gave mixtures which flaked as badly as the control.

Effect of aluminium salts.

The extremely gelatinous nature of aluminium hydroxide is well known and it was thought that by incorporating it with ordinary lime wash adhesiveness might be obtained. Accordingly aluminium sulphate was added. Its reaction with calcium hydroxide gives aluminium hydroxide which thus becomes thoroughly well mixed.

The following mixtures were tried with the results included in the table below:

No.	Lime	Aluminium sulphate	Glue	Copper sulphate	Water	Result
(1)	2	$\frac{3}{5}$	—	—	10	Thick coating when wet, very hard and firm when dry
(2)	2	$\frac{3}{5}$	$\frac{1}{8}$	—	10	Thick coating when wet, but not quite so good when dry as (1)
(3)	2	$\frac{3}{5}$	—	$\frac{1}{20}$	10	Decidedly thinner when wet and powdery when dry
(4)	2	$\frac{3}{5}$	$\frac{1}{8}$	$\frac{1}{20}$	10	Thin when wet and loose when dry

The addition of glue did not improve the mixture, and copper sulphate again caused thinning and loss of adhesiveness.

Substitution of alum for aluminium sulphate.

It being possible to obtain alum at $1\frac{1}{4}d.$ a pound while the cheapest quotation for aluminium sulphate is $2\frac{1}{2}d.$, the former was tried in its place. At the same time iron sulphate was introduced as a fungicide with the results given in the following table:

No.	Lime	Alum	Iron sulphate	Water	Result
(1)	2	$\frac{9}{10}$	$\frac{1}{10}$	10	Too thick
(2)	2	$\frac{9}{20}$	$\frac{1}{10}$	10	Too thin
(3)	2	$\frac{7}{10}$	$\frac{1}{10}$	10	Right thickness

Unlike the copper sulphate, iron sulphate does not cause a thinning of the mixture.

In order to test the rain resisting power of the various mixtures that had been made up, slides covered with them were soaked in water for 24 hrs. The mixtures and results are given in the following table:

No.	Lime	Whiting	Alum	Farina	Glue	Dichromate	Iron sulphate	Cressyllic acid	Water	Result after 24 hrs. soaking
(1)	2	—	$\frac{7}{10}$	—	—	—	$\frac{1}{10}$	—	10	Very good. Still hard
(2)	—	8	—	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{32}$	—	—	10	Resisted fairly well
(3)	—	8	—	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{64}$	—	—	10	Resisted fairly well
(4)	14	7	—	1	1	$\frac{1}{4}$	—	—	80	Resisted fairly well
(5)	20	—	—	—	—	—	—	5	100	Poor
(6)	—	8	—	$\frac{1}{4}$	$\frac{1}{8}$	—	—	—	10	Very poor
(7)	—	8	—	$\frac{1}{8}$	$\frac{1}{8}$	—	—	—	10	Very poor

The mixtures in this table were subsequently tested in the field (see *Field experiments*, 1913–14) when it was found that No. (2) gave by far the best results. As, however, the whiting therein cost as much as $1\frac{1}{4}d.$ in the total of $2d.$ per gallon of wash, it was necessary to try whether lime could be substituted instead. At the time the fact

that gelatine, the essential body in glue, is insoluble in alkaline solutions was not realized. Lime also appears to decompose glue, as a mixture of the two becomes frothy and the glue loses its properties. The following mixtures were tried with the results included in the following table:

Lime	Glue	Aluminium sulphate	Pot. dichromate	Water	Method of mixing	Result
2	$\frac{1}{4}$	—	—	10	Glue added after slaking	Poor coating
2	$\frac{1}{4}$	—	—	10	Glue added to water before slaking. Poured when hot	Poor coating
2	$\frac{1}{4}$	—	—	10	Ditto but poured when cold	Fair coating
2	$\frac{1}{8}$	$\frac{1}{5}$	—	10	Glue added first	Very thin and poor
2	$\frac{1}{8}$	$\frac{1}{5}$	—	—	The sulphate added first	Fairly good coating
2	$\frac{1}{8}$	$\frac{1}{5}$	$\frac{1}{64}$	10	—	Fairly good

None of these mixtures could be considered satisfactory.

Various other substances were added to the ordinary lime wash with the idea of obtaining a firmer coat. These were miscellaneous in nature and may be included for convenience in one table as follows:

No.	Mixture	Result
(1)	Calcium chloride	About as hard as lime alone
(2)	Solar distillate paraffin in emulsion in the lime	Decidedly soft coat probably due to the oil
(3)	Solar distillate and aluminium sulphate	Also gave a soft coat due to the oil
(4)	Various proportions of skim milk	A soft coating due to the fat contained in the milk
(5)	Calcium chloride then waterglass	Very soft and powdery coat
(6)	Cement in the proportions of $1:1$, $1:\frac{1}{2}$, $1:\frac{1}{3}$, $1:\frac{1}{5}$	All gave flaky and soft coatings, the softness increasing with the proportion of cement
(7)	Plaster of Paris in the proportions of $1:\frac{1}{2}$, $1:\frac{1}{3}$, $1:\frac{1}{6}$	Less flaky than the cement mixtures, but the flakiness increased with increased proportion of plaster

The failure of the cement was probably due to its drying before proper setting could take place. Under ordinary conditions cement is mixed with a quantity of water so that it has a chance of absorbing some chemically before the mass dries.

Methods of slaking lime.

During the course of these experiments it was obvious that the firmness of the resulting coat depended largely on the manner of slaking the lime. An experiment was therefore started to find the method that gave the best result. The usual way of slaking lime is to add just sufficient water to allow chemical action to proceed, that is, it

is allowed to "dry slake." From previous trials, wet slaking, namely covering the lime completely with water, promised the best results. Taking always lime two parts to water ten parts by weight the following ways were tried:

No.	Method	Result
(1)	Excess of hot water added (in this case $\frac{1}{3}$rd total required) applied hot	Good coat
(2)	Ditto but applied cold	Not quite so good
(3)	Excess of cold water added	Decidedly inferior
(4)	Slaked dry with cold water. Then full quantity added	Poor
(5)	Slaked dry with hot water. Then full quantity added	Poor

In these trials hot water gave decidedly the best result. This is probably owing to the completeness of slaking thus obtained. Accordingly, further trials were made with the object of getting conditions which should give complete slaking.

The following methods were tried with the results as given in the table below:

No.	Method	Result
(1)	Made up with hot water and not allowed to stand	Thick but very brittle coat
(2)	Made up with cold water and not allowed to stand	Not so thick or brittle
(3)	Slaked with $\frac{1}{2}$ full quantity cold water. Left for 12 hrs., remaining water added and applied	Rather harder than (2) and slightly brittle
(4)	Made with full quantity cold water. Left for 12 hrs. and applied	Fairly thick and not brittle
(5)	Dry slaked and left for 12 hrs. Then made up to full amount of water and applied	Thin but firm coat
(6)	Made up to full dilution and allowed to stand for 12 days	The mixture became very flocculent and the surface covered with a layer of carbonate. When dried on the slide it gave a very soft and powdery coat
(7)	Ordinary lime coating dried slowly in a moist chamber	It produced a hard marbly coat with softer material underneath
(8)	Lime mixture left in small quantities in a large evaporating dish so as to dry slowly	This produced an exceedingly hard and firm coat

The results from Nos. (1) to (5) clearly show that in cases where the lime was slaked slowly, as when a dry slake was given or the mixture allowed to stand for 12 hours, a firmer, less brittle coat was obtained though not necessarily a thicker one. This result was afterwards confirmed by trials in the field. A dry slake gives a very thin and therefore unsuitable coat for an egg cover in practice. No. (8) gave an excellent coat, no doubt due to its slow drying in an indoor atmosphere containing more than the usual percentage of carbon dioxide.

These conditions formed a solid coat of calcium carbonate not only on the surface but in the lower layers as well, thus making an exceedingly hard and smooth coating. Unfortunately these conditions are impossible to obtain out of doors as drying takes place quickly and only small quantities of carbon dioxide are present.

None of the additions made to the lime improved the coat, while most of them made it distinctly worse.

To test whether carbonating before application improved the mixture, carbon dioxide was passed into a beakerful. When poured on a glass slide and dried a brittle coating was obtained which is quite useless.

Field experiments.

These were first arranged on upright flat-sided posts. The results were subsequently found unreliable.

When sprayed on twigs of a tree the coating is subject to violent movings of bending caused by the wind, which are absent in the case of an upright post. It was found that such bendings of the dried coat was largely instrumental in causing flaking. The trial lasted ten days in December during which much rain was experienced.

No.	Lime	Cressyllic	Whiting	Glue	Farina	Dichromate	Alum	Iron sulphate	Water	State when wet	Result after 10 days
(1)	20	2	—	—	—	—	—	—	100	Moderate coating	Largely washed away
(2)	—	—	8	$\frac{1}{8}$	$\frac{1}{4}$	—	—	—	10	Moderate coating	Showed slight signs of thinning
(3)	—	—	8	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{32}$	—	—	10	Moderate coating	Showed very little signs of thinning
(4)	14	—	7	1	1	$\frac{1}{4}$	—	—	80	Moderate coating	Very good and thick coating
(5)	2	—	—	—	—	—	$\frac{7}{10}$	$\frac{1}{10}$	10	Thinned down before applying as too thick to go through nozzle	Very poor
(6)	2	—	—	—	—	—	$\frac{6}{10}$	$\frac{1}{10}$	10	Do. Do.	Thinned in places
(7)	2	—	—	—	—	—	$\frac{5}{10}$	$\frac{1}{10}$	10	Unstrained and thrown on	Thinned in places and flaked
(8)	2	—	—	—	—	—	$\frac{3}{10}$	$\frac{1}{10}$	10	Do. Do.	Thinned rather more than (6)
(9)	2	—	—	—	—	—	$\frac{1}{10}$	$\frac{1}{10}$	10	Do. Do.	Too thin when applied
(10)	$1\frac{1}{2}$	—	—	—	—	—	$\frac{7}{10}$	$\frac{1}{10}$	10	Strained, sprayed, etc.	Showed very little signs of wear
(11)	1	—	—	—	—	—	$\frac{5}{20}$	$\frac{1}{20}$	10	Ditto but too thin	Far too thin
(12)	$1\frac{1}{2}$	—	—	—	—	—	$\frac{3}{10}$	$\frac{1}{10}$	10	Appeared most suitable	Thinned rather badly

Practically both (5) and (6) were too thick to put through a spraying machine. As alum gave disappointing results, aluminium sulphate was substituted to avoid the presence of the soluble potassium sulphate. The following mixtures were tried:

No.	Lime	Al. sulphate	Iron sulphate	Water
(1)	$1\frac{1}{2}$	$\frac{7}{10}$ (= $\frac{7}{10}$ alum)	$\frac{1}{10}$	10
(2)	$1\frac{1}{2}$	$\frac{5}{15}$ (= $\frac{5}{10}$ alum)	$\frac{1}{10}$	10

No. (2) gave too thin a coat while No. (1) appeared satisfactory. The better mixtures of those tried on the upright posts were then sprayed on to trees with the results included in the table below:

No.	Lime	Whiting	Glue	Farina	Dichromate	Al. sulphate	Alum	Iron sulphate	Water	Result after three weeks	Number of trees sprayed
(1)	—	8	$\frac{1}{8}$	$\frac{1}{4}$	—	—	—	—	10	Washed off badly Surface soft	2
(2)	—	6	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{32}$	—	—	—	—	About the same condition as when applied. Surface gritty	2
(3)	$1\frac{1}{2}$	—	—	—	—	$\frac{1}{3}$	—	$\frac{1}{10}$	10	Washed off badly. Surface very flaky	3
(4)	$1\frac{1}{2}$	—	—	—	—	$\frac{1}{2}$	—	$\frac{1}{10}$	10	Ditto	2
(5)	14	7	1	1	$\frac{1}{8}$	—	—	—	80	Washed off rather badly. Surface flaky	2
(6)	$1\frac{1}{2}$	—	—	—	—	—	$\frac{5}{10}$	$\frac{1}{10}$	10	Washed off badly. Surface very flaky, possibly a little worse than (3) and (4)	2
(7)	$1\frac{1}{2}$	—	—	—	—	—	$\frac{7}{10}$	$\frac{1}{10}$	10	Ditto	3

The weather in the three weeks of trial included rain, snow, frost and wind.

Of these mixtures by far the best was (2). The amount of whiting was decreased from eight to six as the larger amount was difficult to incorporate with the water required by the formula. The aluminium sulphate and the alum mixture were disappointing as they had given good results in the laboratory.

To test the effect of keeping lime mixtures for some time before applying them the following formulae were tried with the results included in the table below:

No.	Lime	Water	Method	Result after two months
(1)	2	10	Applied after keeping for 2 days	Stuck better than (2)
(2)	2	10	Applied hot	Not so good as (1)
(3)	2	10	Applied after being froze for 4 days	Came off very quickly
(4)	3	10	Applied hot	Somewhat better but not good

From results from (1) and (2) it is clear that it is best when possible to keep the lime mixture at least some hours before applying. This

result was confirmed in some experimental spraying done in Herefordshire. The explanation is probably this. When lime is slaked, at first there is a violent action which soon subsides. In ordinary parlance the lime is now "slaked" but chemical action goes on more slowly for some hours. A 40 gallon barrel of lime wash made in the evening was still warm the next morning, showing that chemical action had been continuing. If applied directly after the first violent action has ceased, in the words of the grower put on "hot," further slow slaking proceeds when on the tree, resulting in expansions of particles in the coating. The expansion of small particles act like levers on the rest of the coat, pushing and levering off particles that are completely slaked and dry. The net result is that slaking sets in. This, however, is certainly not the only cause of flaking. Wind causes much damage on the smaller boughs. Owing to the bending to and fro of the twig, at first the coat is too small, when the twig is convex, and then too large, when concave. Another cause is frost after wet. Beating rain causes washing off but not flaking. Insufficient slaking explains the fact that good coatings often show completely bare patches sooner than poor coatings. The poor coatings are generally made from partially slaked lime or from a mixture too poor in lime. In each case a more perfectly slaked mixture is obtained but a mixture which is, of course, much inferior in egg covering powers.

A thick mixture like the 2 lbs. to 1 gallon formula, allowing some hours for complete slaking, not only gives a firmer coat but also a thicker one, as one gets more of the very fine particles which are the most important in forming a thick coat. These particles seem so small that they aggregate when wet in an almost gelatinous manner so that the mixture has quite a distinct viscosity. When dry this gelatinous form disappears and does not reappear on wetting.

Of all the washes so far tried the whiting, glue, farina, dichromate formula gave by far the best results and it was therefore tried more extensively at Long Ashton.

It was also tried at centres in the three counties of Gloucestershire, Worcestershire and Herefordshire on trees well infested with Psylla eggs. One trial was spoiled by a subsequent frost cutting all the blossom and another by the fact that the grower sprayed the treated trees with a spring wash. The third, however, was left untouched and though the application of the whiting wash was followed by heavy rain almost before it was completely dry the resulting crop was good and equal to trees sprayed with a summer wash only.

The whiting wash, though it gave good results as regards sticking, presented difficulties owing to the large amounts of hot water required. In order to get the starch and glue into solution about half the total quantity of water had to be hot. This was a serious drawback and a way was sought to overcome it. The fact that starch could be jellied by caustic soda seemed to suggest a possible solution. It was found that starch jellied by caustic soda gave the required thickness to a whiting mixture but that at the same time it had no coherence and gave a very thin coat. With lime, however, not only was the mixture well thickened by this process but it also retained its coherence.

The following mixtures were therefore tried. They avoid the use of hot water:

No.	Lime	Glue	Farina	Soda	Dichromate	Water	How made
(1)	2	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{64}$	10	The soda added before straining the mixture. This resulted in too thick a mixture to strain but it was worked through and applied to trees
(2)	2	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{64}$	10	Lime mixed with half full quantity of water mixture, strained and then the soda added
(3)	2	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{64}$	10	Lime mixed with full quantity of water and strained. Soda then added
(4)	2	$\frac{1}{8}$	$\frac{1}{8}$	—	$\frac{1}{64}$	10	Starch jellied by the heat of the freshly strained milk of lime

Of the first three (2) was distinctly the best but (4) proved better than all, having a good thick smooth coat. It showed however some tendency to flake. It is hoped to extend these experiments this season.

Action of lime wash on insect eggs.

It seemed desirable if possible to ascertain the nature of the action of a lime coating on Psylla eggs since it certainly does have some checking action.

To do this, apple twigs abundantly covered with Psylla eggs were cut off the trees in March. These were covered with various washes and placed in a beaker of water till the eggs of the controls hatched. The mixtures tried were

No.	Whiting	Lime	Glue	Water
(1)	6	—	1	10
(2)	—	2	—	10 applied hot
(3)	—	2	—	10 applied cold
(4)	—	1	—	10

On the control twig the Psylla hatched in abundance by April 18. (1) showed only two larvae hatched. On dissolving off the whiting

coat with dilute hydrochloric acid many were found in a dried up state in the egg which had not hatched. Others remained fresh and juicy within the unhatched egg. They appeared normal but failed to hold later on. Only a few eggs had hatched and of these only two had succeeded in reaching the open bud.

(2) None were found in the buds. On dissolving the lime coat by dilute hydrochloric acid many larvae were found to be unhatched but dried up. Others had hatched but had failed to get more than a little way out of the egg shell. Others had succeeded in escaping from the egg but had been killed while traversing the lime coat. Newly hatched larvae placed on a lime-coated slide become completely covered with lime and usually die in about two hours, during which time they only crawl a very short distance.

In a second twig coated with (2) larvae were found fairly abundantly in the buds. In both twigs no fresh apparently normal eggs were found as was the case in the whiting coated twig, and in both cases, on solution of the lime coat, dried up larvae were found in the resultant solution showing that they were actually present, held immovably under it.

(3) Some were found in the buds. Lime flakings treated with dilute acid showed presence of larvae. On treatment with acid the shoot showed large numbers of hatched eggs, also of larvae dried in the egg shell.

(4) Practically none in the buds. After solution of the lime by acid many hatched eggs were found and a few larvae dried in the egg shell. As in all the limed twigs living larvae were found crawling on the lime.

From these experiments it appears that:

(1) A thick covering largely prevented the appearance of larvae in the buds.

(2) The lime coatings largely prevented rupture of the egg shell and where rupture had taken place many had not succeeded in getting out of the shell.

(3) Of those that had, many did not succeed in getting to the surface.

(4) Of those that had succeeded in getting to the surface a good proportion were killed by the powdery lime adhering to their bodies.

(5) The whiting coat almost entirely prevented hatching but did not have such a desiccating action.

(6) Under laboratory conditions a thin wash as lime one to water

ten produced as good a result as a thick, but under outside conditions a thick coat is necessary in order to allow for the eroding power of weather conditions.

In conclusion I have to thank Prof. Barker for much valuable assistance and many suggestions.

Abstract.

A. These experiments were started to find a cover spray which:

(1) Is thicker than ordinary lime wash;

(2) Resists weather conditions;

(3) Is cheap;

(4) Is easily made.

Of these a formula containing whiting, glue, starch, potassium dichromate and water fulfils the first two conditions. It fails in numbers (3) and (4) as its cost works out to 2*d.* a gallon and it is not sufficiently easy to make as so much hot water is required.

B. If lime alone is used:

(1) It must be used when fresh.

(2) It should be allowed, if possible, to stand for 12 hrs. before application. To do this on a large scale, one-third of the total quantity of water may be added first. When it is to be applied, the other two-thirds can be added. This does away with the necessity of having a large number of tubs.

C. The beneficial action of lime wash on Psylla eggs is due to the mechanical, sealing action rather than to any chemical one.

A PRELIMINARY INVESTIGATION AS TO THE CAUSE OF ROTTING OF ORANGES FROM BRAZIL.

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(With 1 Text-figure.)

Hitherto, so far as can be ascertained from literature and men of long connection with Brazilian exports, oranges have not been successfully brought over to this country on a large scale in a saleable condition. The flavour and size of these oranges would make them a valuable asset to our table as they would arrive in this country at a time (July and August) when supplies from other sources are low.

The great problem which confronts us however is to get the oranges over in a sound condition, as hitherto every consignment to this country has been more or less rotten. The port of shipment from Brazil is Rio de Janeiro which is about 18 days sea-passage from London, and, allowing several days for packing, etc., an interval of at least three weeks would elapse before their arrival on the London market.

In beginning investigations it was arranged that a box of 50 oranges should be sent through a large firm of Brazilian fruit-importers to be packed in the following ways:

4 oranges wrapped in tinfoil;
4 covered with thin tissue paper and buried in dry sawdust;
4 in dried banana leaves;
4 in tissue paper and not buried in sawdust;
4 subjected to steam for a few seconds, the excess of water drained off and then wrapped in tissue paper;
The rest unwrapped.

The various lots were placed in separate boxes and these were then put into one large perfectly closed box. This box during shipment was conveyed as ordinary freight and not in the ship's cooling chambers.

When the oranges reached England their condition was as follows:

How packed	No. of oranges	Number wholesome	Number with traces of rottenness or wholly bad
Packed in sawdust and thin paper ..	4	4	0
Packed in tinfoil	4	3	1
Ordinary tissue paper	4	2	2
Steamed and wrapped in tissue paper ..	4	0	4 very bad
In dried banana leaves	4	3	1
Packed without wrapping of any kind ..	30	About 20	10

From the above table it would indicate that the best series were those isolated by thin paper and dry sawdust and the worst those subjected to heat and moisture.

One noticeable feature about the unwrapped oranges was that wherever a diseased orange occurred a large excess of moisture occurred in the same area. This suggested a line of enquiry as to whether moisture might not help in the spread of the disease.

The sound oranges were used for inoculation experiments and the preparation of culture media.

Two fungi were found on the bad oranges; one was the common fungus *Penicillium italicum*, while the other had short colourless hyphae with small black zygospores and appeared to be one of the *Mucorineae.* It was found impossible to isolate the latter but the former was easily isolated and cultivated on a 3 per cent. gelatine medium mixed with orange juice. This orange juice gelatine was used throughout, sterilised in the autoclave. The pure cultures obtained were used for infecting sound oranges, in some cases spores only being used, in others mycelium, and in others mycelium together with a little culture medium. During the time that cultures were being obtained the skin of the orange was investigated and the various tissues met with tested as regards their chemical composition. Externally a fairly thick cuticle occurs, below which is a single layer of cells with cellulose walls forming a very shallow epidermis, and beneath this a many-layered tissue with cellulose walls and variable size of cells forming a many-layered parenchyma, often filled with small granular cell contents and yellow in colour. Embedded in this yellowish tissue are many oil glands which extend in many instances quite up to the epidermis and buried deep in the tissue at the other, the glands being more or less oval in shape and lined with a single layer of epithelium.

Below this glandular layer another many-layered parenchyma occurs with irregular shaped cells with large intercellular spaces and

somewhat fibrous strands intermingled with them, the walls of this open tissue being of cellulose, similar to that of closed tissue.

Dusting spores on the uninjured skin, laying on mycelium or putting on mycelium together with gelatine medium, it was found impossible to induce the fungus to attack the orange so long as the cuticle of the skin was undamaged, but if the cuticle was pierced with a sterilised needle or small pieces of it were removed with a razor, then the fungus soon attacked the underlying parts of the skin surrounding the oil glands or between the oil glands and the cuticle.

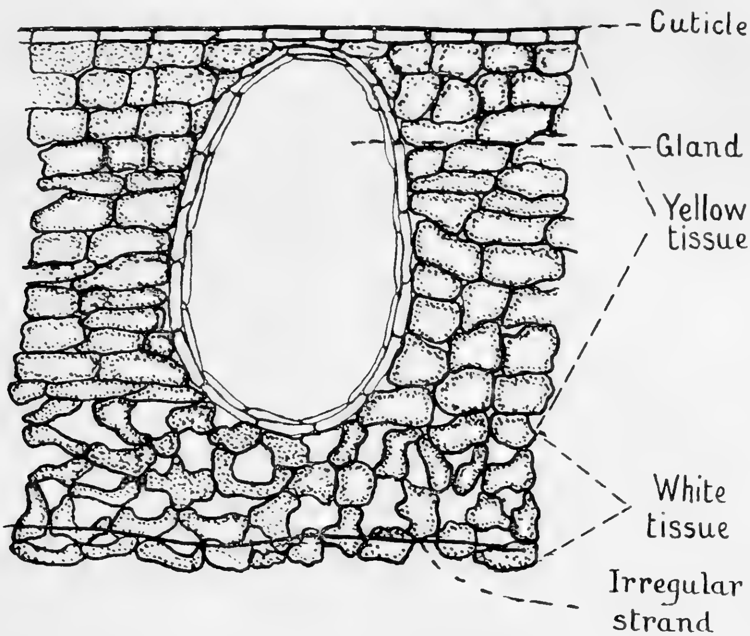

Diagram of section of orange skin.

The first symptom of attack is a brown coloration in the region of infection, which soon spreads in all directions under the cuticle.

Later on the white mycelium of the *Penicillium* appears and follows in the wake of the coloured tissue, and as the discoloration of the tissues continues so the *Penicillium* spreads at the same rate.

On examining this brown tissue no fungal hyphae could be found and it appears that when the fungus gains an entrance into a host it pours out an enzyme which acts on the tissues in the neighbourhood causing them to change colour. This change occurs first in the cell contents and later the cell walls break down.

This brown area preceding the *Penicillium* on the orange also occurs on orange gelatine cultures.

Another change that is undergone by the skin during attack is, that in a sound unaffected orange it is impossible to strip off the cuticle, which can only be removed by cutting the underlying tissues, but when the fungus gets in the cuticle can easily be removed from any of the coloured areas with forceps without any cutting whatsoever. When the attack has become very bad the whole of the cuticle of the orange can be stripped off.

No trace of the fungus piercing the cuticle could be found, although hanging drop cultures of cuticle and fungus were taken.

When the attack is very bad the part of the skin below the cuticle becomes a soft sticky mass, which sooner or later pours out a yellow oily liquid on to the soft surface of the skin together with a large amount of water.

When the orange became soft and pulpy it was noticed that large numbers of small flies appeared on the orange and remained so long as the orange kept its normal shape, but when it completely collapsed the numbers decreased.

It was found impossible to infect a sound orange by leaving it in a vessel with a badly diseased one even in contact with it, but the pouring out of moisture by the diseased one caused the sound one to become covered with moisture and in this way many more spores would adhere to it than would otherwise have taken place and in this way would have a greater chance of finding any slight puncture in the cuticle.

Leaving a sound orange standing in a shallow dish of water the wet portion becomes soft and discoloured and then the cuticle can easily be removed and the tissues attacked with *Penicillium* when removed from the water, but the dry portions out of the water were never attacked unless a previous puncture of the cuticle had taken place.

From these few simple experiments it would appear that the most promising way of sending oranges is that they be kept as dry as possible and in picking and packing care being taken to prevent the cuticle becoming damaged in any way.

Experiments were tried with various chemicals. Solutions of 2 per cent. copper sulphate and 5 per cent. formalin were used on the cut surface of the orange skin and were found to be more or less effective, for if spores were sown on the cut areas the fungicide appeared to check their growth.

The question arises, "Can the oranges be safeguarded from fungal attacks by immersion in some fungicide, or if the spores have already settled in some slight wound can their action be stopped?" Further trials are necessary to solve the problem but the first trials on an extensive scale seem to indicate that *Penicillium italicum* can be checked, but in its stead rottenness due to some other cause sets in; for the first box of oranges sent to me treated with formalin before packing and then packed in dry sawdust, of the three hundred it contained not more than six were sound the rest all being bad, with not the slightest trace of *Penicillium* on them: the cause of rotting appears so far as can be made out on preliminary inspection to cause the fruit to become perfectly brown and somewhat wrinkled, losing their orange shape, the cuticle remains tough and does not come off easily, while the parts of the skin below it are perfectly brown, and suggest a new line of inquiry which I hope to conduct in the near future as further boxes are sent over treated in various ways.

In conclusion I should like to acknowledge my indebtedness to W. Austin, Esq., of London for the trouble he has taken to get the oranges over and to see that instructions were as far as possible carried out to ensure correct information being obtained.

EFFECTS PRODUCED BY SUCKING INSECTS AND RED SPIDER UPON POTATO FOLIAGE.

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(Plates XXIII—XXVII.)

A series of experiments is here described which was designed to ascertain accurately what effects are produced in potato foliage by the action of sucking insects.

The potato plants used were seedlings of the President variety, a variety particularly subject to the curl disease. The first seedlings were raised at Chelsea in 1911 and subsequent series of plants at Chelsea, Wisley and at Messrs Sutton's trial grounds. The greater number were raised at Wisley, 1912–1914, nearly a thousand plants in all.

The raising of these plants from seed, their variability and behaviour under different conditions of growth, and experiments with them not directly concerned with this present work will be described elsewhere.

The objects we hoped to attain and succeeded in attaining were firstly, to be in a position to assign definite symptoms to certain insects and so to be able to eliminate them at once if one is seeking effects produced by fungi or bacteria, as, for example, in the curl disease where pathological symptoms such as dwarfing, yellowness, blotching and dead leaf ends occur; and, secondly, the application of this knowledge in seeking the distribution of pathological conditions due to insects in the field.

A result of this work was the investigation of the mechanism of sucking in two of the species concerned, in *Lygus* by P. R. Awati (*Proc. Zool. Soc.* September 1914) and in *Aleurodes* by E. Hargreaves (*Ann. App. Biol.* I. Nos. 3 and 4).

INFESTATIONS.

The following species were used in making infestations:

1. *Aleurodes vaporariorum* Westd.
2. Red Spider, *Tetranychus telarius* Linn.
3. Aphis, *Rhopalosiphum solani* Theob.
4. Jassid, *Eupteryx atropunctata* Goeze.
   Chlorita viridula Fall (? *C. solani* Koll.).
5. Capsid, *Calocoris bipunctatus* Fabr.
   Lygus pabulinus Linn.

The first three of these, being obtainable early in the year, were used for the first series of infestations, commenced at Wisley on March 22, 1912. Jassids and Capsids were not obtainable until June, hence infestations with these insects were not commenced until after the earlier experiments were completed. Parallel infestations, using the above-mentioned insects, were carried out at Chelsea upon the plants raised at Chelsea.

The conditions under which the experiments with Aleurodes, Red Spider, and Aphis were carried out were as follows: The floor of the greenhouse adjoining the laboratory at Wisley was covered with a layer of garden soil and a number of cloches arranged in rows upon it. Some of the cloches rested directly on the surface of the soil. Under these conditions, if the soil were regularly watered, the atmosphere within the cloches would remain saturated. The remaining cloches were raised above the level of the soil supported on inverted pots so that the air inside the cloche was in communication with the air outside but would be on the whole damper than that of the greenhouse and sometimes saturated.

Four pots were placed under each cloche. Groups of four plants not covered by a cloche were also stationed on the soil.

The experiments arranged at Wisley were as follows:

No. 2. Red Spider. Cloche on inverted pots. Plants watered seldom.

No. 1. Aleurodes. Cloche on inverted pots. Muslin edging to prevent escape of insects. Plants watered regularly.

No. 9. Aleurodes. Cloche on soil. Plants watered regularly.

No. 4. Aphis. Cloche on inverted pots. Plants watered regularly.

No. 3. Aphis. Cloche on soil. Plants watered regularly.

No. 5. Aphis. Plants not under a cloche. Watered regularly.

No. 6. Control. To plants placed under cloches resting on inverted pots.

No. 7. Control. To plants placed under cloches resting on the soil.

No. 8. Control. To plants not under cloches.

No. 10. Control. Pots placed in a vessel containing water, and a cloche inverted over the whole so that the atmosphere remained constantly saturated.

The plants used for the infestations had been uniformly treated, and we selected as far as possible plants of a similar character and equal amount of growth.

Effect on the plants of the conditions under which they were placed.

The plants grown under the cloches soon differed from those not covered at all and the difference was most marked in the case of the plants grown in an enclosed atmosphere. In a constantly saturated atmosphere the plants became larger but procumbent, and developed larger but thinner leaves than the uncovered control (Fig. 1). The plants under cloches resting on inverted pots were less changed.

Several of the plants responded to the experimental conditions by the development of intumescences on the leaves. This feature was more marked in the case of the plants grown under cloches placed directly on the soil.

Red Spider.

No. 2. Four pots, on soil, under a bell-jar raised on inverted pots.

22. 3. 12. Put in leaves of Rhynchosia with many red spider on; the leaves laid between the pots so as not to touch the plants or shade them.

5. 4. 12. Abundant red spider on the plants. The symptoms produced were:
- cessation of growth;
- yellowing of the leaves;
- many minute discoloured spots, giving the leaf a speckled, brownish appearance;
- eventual drying and browning of the plants, which die.

No curling was produced at any time.

One of the plants was photographed on three occasions—April 5, 13 and 17—to show the progress of the infestation. (See Figs. 2, 3, 4.) The experiment was repeated, using leaves from the plants already killed by red spider, with similar results.

It was observed that the plants did not all succumb to the attack at the same time although the chances of being infested were equal.

Aleurodes. Fig. 5.

No. 1. 22. 3. 12. Four pots were placed on soil under a bell-jar raised on inverted pots; 20 flies from Salvia and 24 from potato were liberated under the jar, some escaping.

5. 4. 12. Eggs seen on the leaves; the plants were clean, healthy and similar in appearance.

17. 4. 12. Scale first observed.

24. 4. 12. Young flies observed.

5. 5. 12. Many scales on the leaves, a few empty, the first flies having emerged. There are no symptoms to record; the leaves are not spotted nor noticeably yellow. The control plants, grown under similar conditions but without insects, do not differ from the infested plants.

No. 9. 23. 3. 12. Four pots on soil, under bell-jar raised on inverted pots, with a double muslin curtain containing soil round the lower part of the jar and resting on the soil. Sixty-seven flies from Salvia were liberated.

5. 4. 12. Many eggs on the leaves, some dark, some yellow. Two dead flies seen with a cloud of white threads (? hyphae of a mould). Photographed 9 o'clock.

5. 5. 12. Good infestation of scales. The leaves are slightly yellow as compared with the control kept under similar conditions. There are no other observable symptoms and the leaves are clean, not curled, and well grown.

All the plants infested with Aleurodes were kept free from Red Spider and Aphides.

Experiments set up out of doors were unsuccessful because the plants were killed by frost.

Aleurodes. Gross infestation.

During the course of the experiments described above, the whole of the plants raised at Wisley from the January sowing, and not used for the infestations with individuals, had been kept in a cool frame arranged in series according to the method of potting, kind of soil and origin of the seed. Aleurodes soon appeared amongst them and was allowed to increase unchecked. All the plants were examined critically, one by one, on May 8, and there was noted by one observer the amount of Aleurodes and Aphis, and by the other the characters of the plants themselves, for example, height, whether upright or procumbent, size and shape of juvenile and adult leaves, and the presence or absence of blemishes, such as blotches, pinkness, discoloured veins, yellowness, etc.

The first three series, potted in coarse soil, in large pots, will be considered together since no attempt is here made to draw deductions

between them, but only between the individuals composing a particular series. The series comprise:

Series I. Plants raised from seed obtained from both good and bad plants, Edinburgh.

Series II. Plants raised from seed obtained from good plants, Dunbar.

Series III. Plants raised from seed obtained from bad plants, Dunbar.

The distribution of Aleurodes is shown below.

Distribution of Aleurodes. Series I—III.

	No. of plants in series			
	I	II	III	Total
With eggs, scale and imago	1	1	2	4
,, ,, and imago	3	2	4	9
,, ,, ,, scale	1	1	4	6
,, ,, only	4	2	1	7
,, scale ,,	5	4	5	14
,, imago ,,	0	3	1	4
Without eggs, scale and imago	8	4	6	18
Total	22	17	23	62

There is not any very marked difference between the three series and we may look at the whole 62 plants together:

There are 18 with no Aleurodes in any stage,
Nine in which eggs and flies are abundant, scale few,
Fourteen in which scale is abundant only,
Six in which both scale and eggs are both noticeable.

Without unduly straining the figures we may say that the plants have been unequally selected by the flies of each brood and that there is a very high percentage (29) of plants that have been avoided: is this selection correlated with any plant character that can be noted?

We have been unable to find any character of the plants which we can correlate with the presence or absence of either the scale form or the eggs: clearly there is a connection between the presence of Aphis and the discoloration of the veins: there is no connection between the blotching and the presence of either Aphis or Aleurodes; and there is not any character that we could note which is correlated with a marked presence or absence of either the scale form of Aleurodes or its eggs. It has been possible to note only certain physical characters: it is possible that there is a character connected with the condition of the leaf surface, or the texture of the leaf, or the composition of the cell substance or sap

which does determine whether the fly lays eggs on a plant or not: we believe that there must be some such character which is not revealed by the physical characters that we can note. Had there been a marked difference between the character of the foliage in Series I—III we could perhaps have found some such character as is discussed in Series III, but there is not sufficient difference in this respect to make it discernible.

Series IV.

Plants from seed from Edinburgh and Dunbar, still in small pots. These are markedly less infested and it was possible only to note them as having either no scale at all, scale numbering from one to ten or scale clearly exceeding ten on the whole plant.

Edinburgh:
Clean 20
Under ten 18
Over ten 16.

Dunbar, seed from healthy plants:
Clean 17
Under ten 8
Over ten 5.

Dunbar, seed from diseased plants:
Clean 10
Under ten 11
Over ten 2.

Total:
Clean 47
Under ten 37
Over ten 23.

In this series also there is uneven distribution of Aleurodes and, seeing that these plants had been kept side by side with the series in larger pots which are more infested, it was suggested that the fly selected for egg-laying those plants with more foliage or with healthy foliage not likely to fall off. The plants as classed above for amount of Aleurodes were then grouped according to the amount and condition of their foliage, the resulting figures being:

Clean plants	Bad foliage	23	Good foliage	21
Under ten plants	,, ,,	12	,, ,,	24
Over ten plants	,, ,,	4	,, ,,	19

These figures point, not very decisively, to the fly selecting for egg-laying those plants with more leaves and more perfect ones; this may mean (1) the fly prefers itself to repose on such foliage, (2) it prefers to feed on such foliage, or (3) it definitely selects such foliage for egg-laying on. On this point we can only say that there is a fair concurrence of plants on which flies were found as well as eggs: that is that the plants on which the flies sit and feed are also those on which they lay eggs (see Series I—III). It is noteworthy that there is very much less scale on the far smaller plants of Series IV than of Series I—III, though they were throughout kept together; there is no plant in Series IV which in Series I—III would have been marked as more than "scale moderate." This may be due to the Series I—III plants being in higher pots and so nearer the light or to their greater amount of foliage.

It seems to be quite clear that there is a definite selection of plants by the Aleurodes which may be connected partly with foliage but must also depend upon some other character that we cannot determine.

Aphis. Figs. 6, 7.

No. 3. Four pots on soil under bell-jar placed on the soil.

22. 3. 12. Placed twelve Aphides on each plant. These were of varied size, including in each case two winged forms, and were taken from potato plants growing in pots.

26. 3. 12. Intumescences observed in the plants.

1. 4. 12. Some leaves with discoloured veins.

2. 4. 12. The Aphides were counted, being 43, 14, 6, 16 respectively on the four plants.

5. 5. 12. One Aphis found on each plant.

No. 4. Four pots under a bell-jar which is raised on inverted pots leaving a space between the jar and the soil. Put in Aphides from the potato plant on 22. 3. 12.

1. 4. 12. The Aphides total 97, 40, 19, 54 on the respective plants.

Some leaves with discoloured veins.

5. 5. 12. A heavy infestation, the most Aphides on the lower surface of the lowest leaves. The symptoms noted are:

yellowing of the leaf generally;
the veins on the lower surface become dark coloured;
the leaf tips and margins become brown, dry and brittle;
the leaf eventually falls off.

No. 5. 22. 3. 12. Four pots uncovered, each infested with 12 Aphides from a potato plant.

1. 4. 12. Several leaves with discoloured veins in all the plants.

2. 4. 12. Aphides on plants number 46, 89, 108, 103 respectively.

5. 5. 12. Three plants very heavily infested, one not. Of the infested ones, one is withering, the leaves limp, yellow, curling and browning at the tips, the veins dark; two have the leaves yellow, the veins dark, the tips brown. The plant now free had the veins heavily dark, the leaves browning off from the tip.

Since the plants of No. 5 were not confined, they became infested with Aleurodes which was present in the greenhouse. The flies were continually removed to the extent that scale was present on only one plant on April 19.

A comparison with the controls shows that these symptoms were undoubtedly due to Aphis. The plant under Cloche 7, control to Aphis 3 (plant enclosed), did not develop discoloured veins (Fig. 8), either on the leaves present at the time of the infestation or on the leaves newly formed whilst under the cloche. The plants under Cloche 6, control to Aphis 4, were with difficulty kept free. On April 2, 106 were removed, 48, 8, 40 and 12 respectively on the four plants, and the veins of some leaves on the third and fourth plants were slightly discoloured. The plants under Cloche 8, control to Cloche 5, were not enclosed and hence exposed to repeated infestation. The Aphides were frequently removed, 53 were removed on April 2 and the veins were not discoloured, but soon a relative difference only could be observed between the infested and control plants and the two sets soon became equally and heavily infested.

From the above results it will be seen that the earliest symptoms due to Aphis show themselves on the leaves, the midrib and veins of which become brown, and that these symptoms appear, irrespective of the conditions under which the infested plants were placed, within ten days from the date of infestation.

The further progress of the infestation and the development of later symptoms were, however, influenced by the conditions under which the plants and Aphides were kept. On April 1, the distribution of Aphides was as follows: Cloche 3, 79; Cloche 4, 210; Cloche 5, 346; a result showing that the Aphides multiplied most on the plants not confined, least on the plants entirely enclosed. In fact they gradually decreased in number on the enclosed plants until on May 5th only four remained.

The symptoms rapidly increased on the plants not enclosed, the leaves becoming yellow, the veins dark brown, and the leaf tip curled, brown and dead.

Gross Infestation by Aphis. Chelsea.

The Chelsea plants were examined by one observer on May 17 and their characters noted. They were very different in appearance from those raised at Wisley, being on the whole taller with more slender stems and the leaves much smaller. No less than nine plants had developed two or more slender stems instead of one, thus greatly modifying the general appearance. The characters yellowness, pinkness, and blotch, characteristic of the Wisley series, were entirely absent, but five plants possessed hooded or curled leaves—the margin bent downwards—a character absent from the Wisley plants. No insects were observed upon the plants on May 17th.

The plants were examined critically by the other observer for insect characters on June 11. These had been free of all insects except Aphis, which had been allowed to increase on the plants for three weeks unchecked, the plants then being evenly and lightly infested. The plants were examined individually and the points noted for each (as these proved to be the same throughout it is not necessary to reproduce them in full). The following points should be noted:

All the plants had colonies of Aphis on the large old leaves. Leaves lightly infested showed no definite symptoms: darkening of the veins occurred in all cases of more than light infestation and the oldest leaves also showed marked yellowness, not necessarily due to Aphis.

In cases of severe infestation the tip and edges were brown. Old broad leaves were not quite flat but curved: curling was not seen. Small leaves were in many cases sharply curled, but this symptom was not coincident with the presence of Aphis nor with the occurrence of dark veins. Aphis was present in many cases on the small leaves, but on picking out all plants with curled leaves these were not markedly infested with Aphis on the small leaves.

There is no evidence of Aphis selecting plants; all had Aphis on now or had signs of previous occurrence of Aphis.

Gross infestation by Aphis. Wisley.

A series of seedlings raised later than Series I—IV was examined for Aphis on July 24. On this occasion there were three plants with curled leaves and Aphis was absent from two of them.

A series of 80 plants raised from the original stock of seed, in 1914, and exposed to infestation yielded a somewhat different result. Thirteen plants exhibited hooded or curled leaves and all were infested

with Aphis. The youngest leaves were chiefly affected and infested, but in this case they were often considerably distorted and their veins discoloured.

Jassid series. (A) Wisley.

1. June 5. Three plants were infested with 10, 9 and 9 Jassids respectively, Eupteryx species and a green species.

June 8. Small white spots were present in the infested plants but absent on the controls (Fig. 9).

The spots are about 1 mm. in diameter and possess an irregular outline. When a number occur close together, whitish blotches or patches are formed, more usually on the upper surface of the leaf. The spots are not confined to the young leaves and do not occur in sufficient number to cause the death of the leaf directly. The tissue of the leaf is not lacerated as in the case of injuries caused by Capsids. The epidermis is punctured and the proboscis of the insect injures and destroys the chlorenchyma. The white appearance of the spot or blotch is due to the loss of chlorophyll and perhaps an optical effect, in part, due to included air.

2. June 11, 3 p.m. Single plants infested with one Eupteryx collected at Wisley.

June 12, 10.30 a.m. White spots present on one leaf. Eupteryx still alive. The spots have been produced within 20 hours.

Jassid series. (B) Chelsea.

June 9. Put three clean plants under a bell-jar with two winged *Eupteryx atropunctata.* Controls all clean plants unspotted.

June 11. Removed the bell-jar and the two bugs; observed small light spots on several leaves; controls not spotted.

June 13. The spots are slightly brown.

June 20. The spots are larger and in some cases have become holes.

Capsid series. (A) Wisley (Fig. 10).

1. June 12. Put one clean plant under cloche with four wingless green Capsids collected at Wisley.

June 13. Small brown spots observed on youngest leaves.

2. June 12. Put one clean plant under cloche with two green winged Capsids collected at Wisley.

June 13. The following symptoms had developed:

black stripe along petiole;
dark blotch on leaf lamina;
young leaves with dark brown irregular blotches on the upper surface.

3. June 12. Put one clean plant under cloche with two brown winged Capsids collected at Wisley.

June 13. No visible result.

4. June 12. Put one clean plant under cloche with three small green and brown grass Capsids.

June 13. No visible result.

5. June 12. Put one clean plant under cloche with one striped nymph off grass.

June 13. No visible result.

6. June 14. Put one clean plant under cloche with three Capsids collected at Wisley.

June 15. No visible result.

June 17. Youngest leaves with brown blotches.

7. June 14. Put one clean plant under cloche with nine Capsids collected at Oxshott.

June 15. Small brown spots appeared on the youngest leaves.

June 17. Attack severe. All the youngest leaves spotted and blotched and nearly dead. Six Capsids were observed.

8. June 14. Put one clean plant under cloche with one Capsid collected at Oxshott.

June 17. No visible result.

Capsid series. (B) Chelsea.

1. June 11. Put three clean plants under a bell-jar with one green winged Capsid and one green nymph in the last stage, both collected at Wisley that day.

June 13. No visible result. Added two green nymphs from Walton.

June 20. One plant has the small foliage with holes edged with brown. Another plant has two leaves the same. The third plant shows nothing.

2. June 11. Put two clean plants under a bell-jar with ten unwinged green Capsid nymphs, collected that day on potato plants at Wisley.

June 13. No visible results. One winged form, the rest nymphs.

June 20. The small leading shoots are brown and dead. The smaller leaves have holes edged with brown.

No control shows these symptoms at all; apparently the Capsids feed on the shoots and youngest leaves and give rise to holes in the leaves and to the death and browning of the apical shoots. This effect has not occurred on any plant at Chelsea except those infested with Capsids. (The action of Eupteryx on the leaves is exactly the same as that at Wisley.)

Capsid symptoms.

In these experiments the insects attacked the youngest leaves and small irregular spots or blotches were formed which were either scattered or so numerous as to give the leaf or leaflet a brownish appearance. Each spot when first formed possesses a clear centre with a brownish boundary. The spots are due to the laceration and destruction of the tissue at the places where the insects feed—either on the upper or lower surface (usually the latter) of the leaf. Small pits are formed which often extend to the opposite epidermis and the leaf may be perforated or if not, perforation soon takes place. The dark boundary to the spot is evidently due to the discoloration of the broken cells which form the wall of the pit. Veins near the pit are lacerated, discoloured and sometimes severed. When the attack is severe, the chief veins of the young

leaves are partly severed, so that the leaf or leaflet soon withers and dies. In severe cases the young shoot dies.

The discoloration of the veins caused by Capsids occurs rapidly after the infestation and discoloured veins are associated with the presence of lacerated pits or areas. Discoloured veins due to Aphis develop after several days have elapsed since the infestation and they are not associated with lacerated tissue.

The difference in symptoms produced by the Capsid and Jassid is accounted for by different structure of the stylets of the mouthparts. P. R. Awati (*Proc. Zool. Soc.* 1914, p. 685) figures the mouthparts of *Lygus* and shows that the outer pair of stylets (the mandibles) are barbed; when they are withdrawn the plant tissue is lacerated. In the case of *Eupteryx*, the outer stylets are smooth and they can be withdrawn without further injury than that caused by the sucking.

The mechanism in *Aleurodes* is described in another paper above by Hargreaves, but further work is required to compare the action on the plant-tissue of the sucking mechanisms of *Lygus*, *Eupteryx*, *Rhopalosiphum* and *Aleurodes* respectively. The actual structure of the mechanism is not sufficient; we are ignorant of the action inside the plant.

FIELD OBSERVATIONS.

We are enabled to report upon insect injuries to potato foliage at the following places:

1.	Barley (Herts).	Potato breeding experiments by Dr Redcliffe N. Salaman.
2.	Brentford.	Private garden.
3.	Chelsea.	Experimental plots at the Physic Garden.
4.	Dunbar.	Field crop.
5.	Edinburgh.	Field crop.
6.	East Lothian.	Field crop.
7.	Midhurst (Kent).	From specimen.
8.	Oxshott.	Private garden.
9.	Reading.	Messrs Sutton's trial grounds.
10.	Strawberry Hill.	Private garden.
11.	Walton-on-Thames.	Market garden.
12.	Wisley.	Trial and experimental plots.
13.	Woking.	From specimens.
14.	Wye (Kent).	Experimental plots.

Field observations on Aphides.

Aphides were very closely under observation at Wisley in 1912. On July 5 it was found that some varieties were badly infested and others not at all. These Aphides were not observed on the Duke of York; a few were found on Arduthie Early and Ringleader, associated with discoloured veins, whilst there occurred among a single row of Sharpe's Express, twelve plants with dead foliage, eight with foliage undoubtedly killed by Aphides and six with foliage still green. In several cases the original injuries caused by Aphides had received secondary extension owing to a period of wet weather—the portion of the leaf-blade next the discoloured mid-rib first decayed, the decay spread and ultimately involved the whole leaflet. In spite of the presence of numerous Coccinellids, the Aphides appear to have got the upper hand.

Certain varieties grown in another part of the Wisley Garden and including the Duke of York, the Sutton Flourball, Up-to-Date, Langworthy, Northern Star and President were scarcely affected by Aphides, although these were present throughout the season. Coccinella was abundant here also but appears to have held the Green fly in check.

Diseased plants received at the Wisley Gardens from Woking on July 2, 1912, were stated by the sender to have stopped growing at quite an early stage, and bore only six tubers of very small size. The plants showed similar symptoms to those which appeared on the Sharpe's Express variety at Wisley—discoloured veins and a secondary extension owing to bad weather. Living Aphides were present on the specimens and the disease was certainly caused by them.

Similar specimens with remains of Aphides upon them were received from Midhurst on July 6. The sender had been advised that owing to disease in the haulms, potatoes should not be grown on the same ground for two years. The haulms were not diseased, the condition of the plants being again due to Aphides.

Owing to the kindness of Dr Redcliffe N. Salaman we were enabled to study the experimental races of potatoes raised by him at Barley in 1911 and 1912. It was observed in 1911 that the foliage of certain races was badly diseased, whilst the foliage of other races remained almost entirely healthy. The chief symptoms of disease took the form of brown blotches, dead leaflet-ends, and perforations, but no attempt was made to ascertain the cause of these symptoms then.

In the following year there was a recurrence of the phenomena already mentioned, whilst again certain races remained quite healthy; nevertheless, the foliage of almost every plant of other races was badly diseased. The whole question of the disease in the foliage at Barley cannot be discussed here, since it must be considered in relation to all the conditions under which the races in question were raised and grown. Three types of injury could be distinguished:

1. Blotched foliage not associated with discoloured veins, neither insects nor their remains present.

2. Badly blotched foliage associated with discoloured veins and Aphides.

3. Blotched foliage associated with the presence of Capsids.

A great deal of the damage was certainly due to a secondary extension of the injuries primarily caused by insects, owing to a period of bad weather following the infestation. Coccinella was not present in abundance.

By kind permission of Messrs Sutton, the firm's potato trials at Reading were visited in 1912. The plants were remarkably free from blemishes of any kind and on several varieties, notably Garden Favourite and Maincrop, no injuries due to insects could be detected at all. Amongst plants of Windsor Castle only one was infested with Aphis. Several plants of the Up-to-Date had been attacked and showed the characteristic brown veins. Curiously enough the Up-to-Dates were adjacent to other varieties from which insect injuries were absent. Coccinella was abundant.

Field observations on Capsids.

The President plants grown at Wye in 1911 were practically free from insect injuries, but they were also free from blotches or discoloured veins. On July 30, 1912, Professor Theobald informed us that he had observed nothing but a few Aptera and some Capsids on potato plants at Wye in that year.

The plants raised at the Chelsea Physic Garden in 1911 were badly blotched and it is now quite clear that the condition of the foliage was due to Capsids. On June 28, 1912, the plants grown from tubers in the open at Chelsea were more carefully examined for insects. Several plants had been injured by Capsids and many Capsids were observed.

The first Capsids used for experimental purposes were captured at Wisley on June 11, 1912. This was almost their earliest appearance at Wisley. On June 17 Capsids were active at Oxshott, especially on

the Duke of York variety. They blotched and killed many of the young leaflets and young shoots.

Soon after the appearance of Capsids at Wisley a large market-garden at Walton-on-Thames was visited. Here the foliage of a great number of plants exhibited blotching in some form or another, but the marks could not be attributed to the agency of insects nor fungi. Capsids were observed only on the Eclipse and at this early date had caused but little damage.

Capsids were in abundance at Reading on July 3 among plants of the Up-to-Date, and the foliage of several plants was badly blotched. Varieties adjacent to the Up-to-Dates appeared to be quite free from these insects.

Capsids were occasionally abundant during June and July 1912 at Wisley. Brown spots due to Capsids were especially noted on Arduthie Early and a few plants of the Duke of York.

Brown spots due to Capsids were observed on potatoes near Cobham on July 15.

Capsids were responsible for some of the damage observed at Barley in July 1912. Many blotches had been recently caused by these insects, other markings were secondary extensions from blotches formed prior to the wet weather. Many young Capsids were found amongst the plants in question.

At Brentford the action of Capsids generally on potato and other plants was followed during 1913 and 1914. In both years the same sequence occurred: red currant (Fig. 11) was first heavily attacked and the foliage very much destroyed during April—May; then the Capsids went to mallow, cherry (Fig. 12), some other weeds and potato (Fig. 13); the potatoes developed quite normal signs of attack; the bugs then went to Jerusalem artichoke (*Helianthemum*). The life-history has not been worked out in detail, but the sequence of young and adults suggests three broods a year.

The symptoms described above as produced by *Lygus* and *Calocoris* under control are easily discernible in the field and a little searching reveals the nymph or imago of one of the common species.

Field observations have been directed only to determining how far these bugs are definitely associated with symptoms on potato foliage. We think that the bugs deserve far more attention as general garden pests and that far more damage is being done than is generally supposed. This is, of course, no new observation. Theobald (*Ent. Mo. Mag.* 1896, p. 60; *Journ. Bd. Agric.* London, 1909, p. 568) has drawn attention to

Calocoris fulvo-maculatus de G. Carpenter (*Report* for 1896) refers to *C. bipunctatus* F. and to *Lygus pabulinus* L. (*Report* for 1911). Theobald also refers to *L. pratensis* L. (*Report* for 1904, p. 63) and there are a number of references to these species by continental authors. So far as we are aware, these describe attacks observed in the field, not symptoms definitely produced experimentally.

Field observations on Jassids.

Potato foliage was marked with white spots caused by Jassids in many localities in 1912, and these insects were in every case observed in the leaves. The spots were usually scattered and infrequently united to form moderately large areas, and did not involve the whole leaf surface, giving it a whitish appearance, as may frequently happen in the case of the rose and various fruit trees.

The very characteristic white spots can be seen in the field on potato at once and *Eupteryx* is in all cases found there. Similar spotting can be seen on rose, plum, cherry (Fig. 14) and apple in the early stages of Jassid attack, but in 1913, 1914 the attacks became so severe that the whole leaf became yellow.

Such attacks are well known in England and have been described by Theobald and by Curtis.

Summary.

1. Definite and similar symptoms apart from any other cause were obtained as the result of infesting young plants raised from seed of the President variety of potato with Red Spider, Aleurodes, Aphis, Jassid, and Capsid under various experimental conditions at Wisley and Chelsea as follows:

(*a*) Red Spider.—Leaves became mottled, plant turns brown and dies.

(*b*) Aleurodes.—Effect gradual, plants weakened but did not die.

(*c*) Aphis.—Leaves with discoloured veins, brown and dead leaf-ends, yellowing and death of the plant.

(*d*) Jassid.—White spots, plants did not die.

(*e*) Capsid.—Dark brown blotches on leaves and young growth, veins darken, young leaves and shoots killed rapidly.

These symptoms did not develop in the controls except in the cases where the control plant became infested by the particular insect experimented with.

2. The effect on the foliage tissue in each case is as follows:

(*a*) Red Spider.—Epidermal and sub-epidermal cells injured.

(*b*) Aleurodes.—Conducting tissue tapped, not followed by vein discoloration.

(*c*) Aphis.—Conducting tissue tapped followed by vein discoloration after nine or ten days.

(*d*) Jassid.—Epidermis punctured, assimilatory tissue destroyed.

(*e*) Capsid.—Tissue lacerated causing severance of the veins and leaving ragged, irregular pits which become rapidly discoloured as do the veins also within two days.

3. The markings caused by Jassids and Capsids proved distinctive and could be recognised as such for some time after the injury, but for the safe recognition of Aphis injuries the association of typical markings with Aphides or their remains is necessary.

4. Evidence has been obtained that Aleurodes select plants.

5. Definite symptoms due to Aphis, Jassid and Capsid, correlated with the presence or remains of these insects, have been found in the field crops in several districts in three consecutive seasons. During and after periods of wet weather the original injuries, especially those caused by Aphis and Capsid, frequently obtain secondary extension, and the foliage is prematurely destroyed.

6. From field observations Aphides appear to exhibit a preference for certain varieties or races of potato, but the question of selection has not been experimentally studied by us.

Fig. 1. Plant in saturated atmosphere (left) and in the open (right).

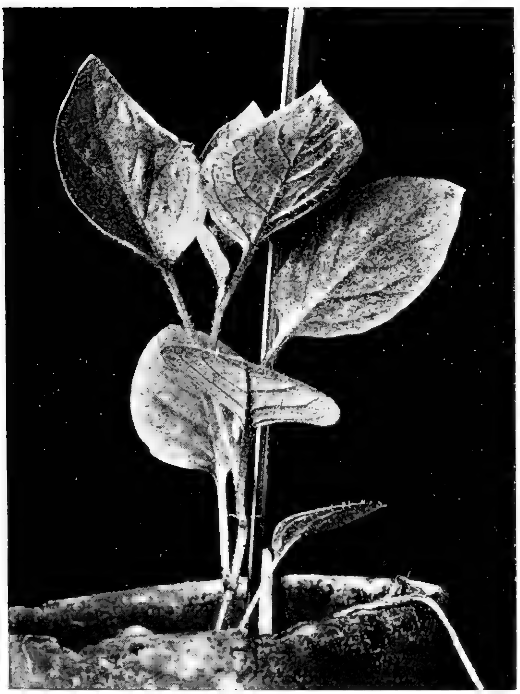


Fig. 2. Early Red Spider attack.

Fig. 3. More advanced Red Spider attack.

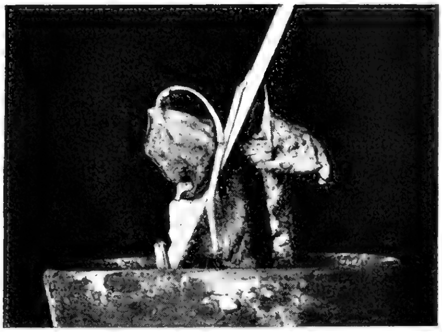


Fig. 4. Last stage of Red Spider attack.

Fig. 5. Aleurodes adults on plant.

Fig. 6. Aphis on underside of leaves.

Fig. 7. Result of Aphis attack. Note black veins on lowest leaf.

Fig. 8. Control plants to Figs. 6 and 7.

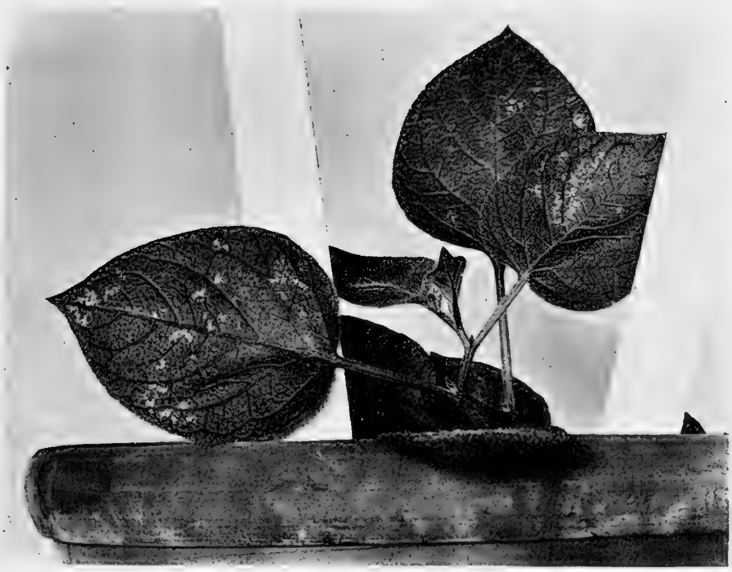


Fig. 9. Results of Jassid attack.

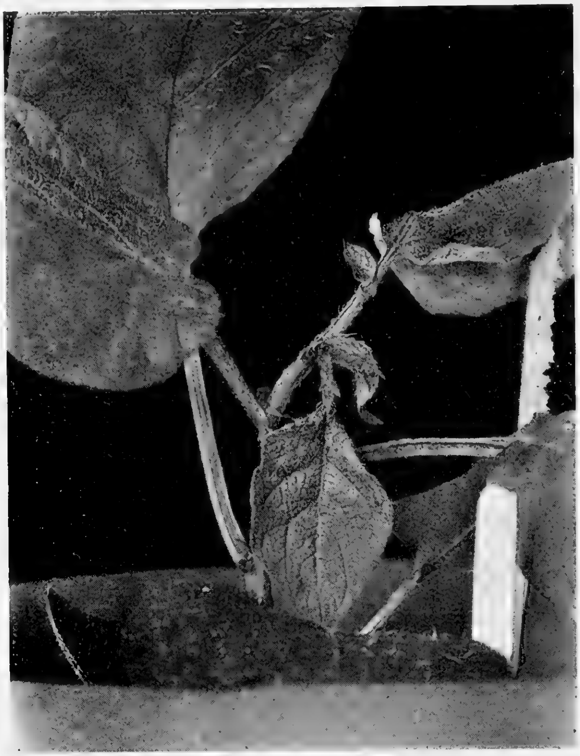


Fig. 10. Capsid attack.

Fig. 11. Red Currant shoots injured by Capsids.

Fig. 12. Cherry leaf injured by Capsids.

Fig. 13. Potato foliage injured by Capsids.

Fig. 14. Cherry leaf injured by Jassids.

NOTES.

The Association.

A meeting of the Association has not been held since July and the number of members who attended that meeting was not large. A circular was sent to all members in the United Kingdom asking if they would attend a meeting in September: replies were received from about a quarter and only one member was prepared to attend. The meeting was postponed for other reasons.

With this issue we complete the first volume of the *Annals*, the material for the third and fourth numbers being issued as a single part. This has been rendered necessary by events over which we have no control and it is hoped that the first part of the second volume will be issued by the end of March.

Two features of this issue are of special interest. We welcome the papers by Dr Barber and Mr Anstead dealing with problems of tropical agriculture, and we hope to receive many more contributions from members in the tropics. The second feature is the number of shorter articles and notes, dealing with a wide range of topics. Members will assist the *Annals* specially by contributing such short articles and notes.

We include in this issue a review; the publication of critical reviews of important new books should become a feature of the *Annals*. Volumes for review should be sent to the editor, who will send them on to the member of the Editorial Committee concerned.

The *Annals* are sent in exchange to a number of biological publications. Members of the Association can consult the journals received in exchange at the Association's Library in the Royal College of Science, South Kensington. The following are received:

Annales du Service des Epiphyties, Paris: *Bollettino del Laboratorio di Zoologia*, Portici: *Journal of Agricultural Science*, Cambridge: *Quarterly Journal of Forestry*, Oxford: *Redia*, Firenze: *Journal of the Royal Horticultural Society*, Westminster:

Transactions of the Royal Scottish Arboricultural Society: *Bulletin of Entomological Research*, S. Kensington: *Review of Applied Entomology*, S. Kensington: *Tijdschrift voor Pflanzenziekten*, Wageningen: *Monthly Bulletin* and *Bulletin Bibliographique*, International Institute of Agriculture, Rome: Publications of the United States Dept. of Agriculture: *West Indian Bulletin*, Barbados: *Agricultural News*, Barbados: *Agricultural Journal of India*, Pusa: *Memoirs of the Agricultural Dept.*, Pusa: *Bulletin of the Agricultural Dept.*, Trinidad: *Bulletins of the Indian Tea Association*, Calcutta: *Gardens Bulletin*, Straits Settlement.

We shall be glad to consider other exchanges and members will find it useful to know that they can consult current numbers of these publications in London.

The library has been added to by the gift of many separates and other publications by members; there is room for much more and members attention is again directed to this. We are laying the foundation of the future library of Applied Biology and if members will co-operate the library will presently be of real value to all workers.

H. M. L.

AMERICAN GOOSEBERRY MILDEW.

At the last meeting of the Economic Biologists Association, Mr Salmon read a paper on some observations on the "Life History of the American Gooseberry Mildew" in which the theory was advanced that the over wintered perithecia of the fungus that remain on the bushes were sterile and could not reproduce the disease in the following season.

Shortly after the paper was read, viz. 24th April 1914, shoots badly affected with the mildew were collected in Kent by one of the Board's sub-inspectors. They were submitted to Kew with a request that they should be examined and the ascospores germinated if possible. Shortly afterwards (6th May) the following report was received: "A considerable number of the perithecia or winter fruits present on the material sent to Kew were sterile. Others, however, contained normal spores, some of which have germinated. The mycelium shows no sign of life, and judging from the absence of oil globules and stored food material must be dead." A further sample was submitted on the 7th of May, and on the 18th the following report was received: "The majority of the perithecia present on the shoots are much smaller in size than the normal ones and represent the morbid and imperfectly

developed examples that are apt to occur in every crop. Such remain permanently attached to the mycelium. A few normal perithecia containing spores that have germinated were also present. The mycelium has shown no sign of life."

In both of these cases the bushes from which the shoots were taken developed disease in April. A very large number of other bushes in different gardens in Kent developed disease in April also, but in practically every case the diseased shoots had not been entirely removed, and in no case did the mildew appear in that month on any bushes from which the diseased shoots had been removed early in the preceding summer.

Furthermore about the middle of May specimens were sent to the Board by a private grower in Sussex with a request for information as to the nature of the disease. American Gooseberry Mildew was suspected since the berries showed the characteristic white oidium. The writer, however, asserted disease had not been present the year before. On examination, however, old dead mycelium was found on the old wood about an inch or less from the affected berry. This mycelium contained a number of perithecia which presented the appearance of having dehisced *in situ* and the presumption that the infection on the berry is due to the ascospores from these perithecia is at least strong enough to merit consideration.

The two reports received from Kew together with the strong empiric evidence collected by the Board's Inspectors as to the conditions under which early infection occurs appears to me to outweigh the evidence collected by Mr Salmon and published in his papers, and I submit that until much fuller evidence is obtained it would be a great pity to allow growers to suppose that they can ignore the over wintered perithecia on their bushes. All the officers of the Board who have had any experience of this disease are agreed that early tipping is essential for complete success against the disease, but they are I believe all agreed that a partial success may be obtained by late tipping, and that much good may be done by going over the bushes even as late as February or March and removing the affected snags which were overlooked when the bushes were tipped before the leaves fell. The removal of every scrap of disease in the summer or early autumn while the leaves are still on the bushes is a matter of great difficulty. No one suggests that the first tipping should be delayed so long.

Mr Salmon states in the last paragraph of his paper that if tipping is not carried out till the end of October or the beginning of November,

a considerable mass of perithecia must have dropped from the perithecial patches. Many of these perithecia would doubtless lodge in the crevices of the bark or between the bud scales, etc., and assuming that these perithecia were mature ones capable of remaining dormant through the winter, these would on liberating their ascospores infect the adjacent berries. This is a theory to which he says on the whole he inclines. It is of course a very old theory and was, I believe, advanced by the Board in one of their earlier reports, but as I have never heard of any case in which the spores were found in the crevices or scales and as it has been shown that if the visibly affected wood is removed and the bushes transplanted to uninfected soil no disease appears, the theory appears to lack support and it seems to be at least as likely that the reinfection each season is due to the winter fruit in the soil or embedded in the mycelium and due to perithecia dehiscing *in situ*.

A. G. L. ROGERS.

EXOMIAS PELLUCIDUS AS A PLANT PEST.

On May 14th, 1914, an enquiry was received from Charles Townsend, Nurseryman, Fordham, concerning the damage done to a number of plants by the weevil *Exomias* (*Barypeithes*) *pellucidus*. A visit was paid to the Nursery on May 16th and the weevils were found there in enormous numbers.

The plan of the nursery is on the opposite page:

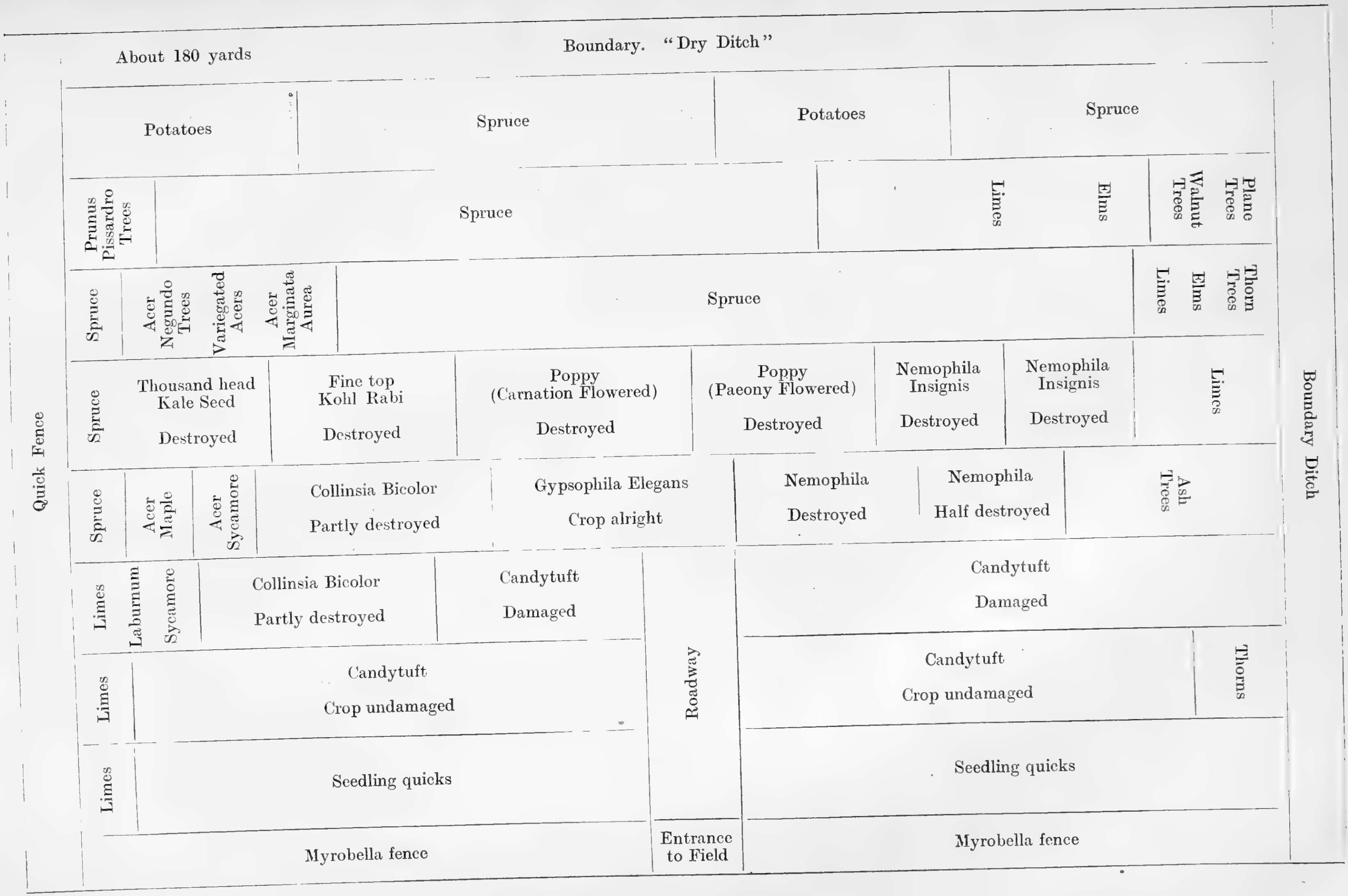
The Thousand heads, Kohl Rabis, Poppies and Nemophylas were all eaten off so that the ground was bare.

The *Collinsia bicolor* and Candytuft were badly damaged and were only saved by a heavy application of lime and soot. The plot containing *Gypsophila elegans* escaped although situated in the middle of the area attacked, so presumably this is not a suitable food for the insect.

Some of the trees were examined and a few of the weevils were found feeding on the leaves of *Acer marginata aurea* and *A. negundo variegata alba*. The potatoes, peas and spruces were free from attack.

Near the attacked area under the spruces large numbers of the insects were found.

There were some rabbit burrows on the nursery and from these it was quite easy to take out a handful of the insects. They had



About 180 yards
Boundary. "Dry Ditch"
Potatoes
Spruce
Potatoes
Spruce
Prunus Pissardro Trees
Spruce
Limes
Elms
Walnut Trees
Plane Trees
Spruce
Acer Negundo Trees
Variegated Acers
Acer Marginata Aurea
Spruce
Limes
Elms
Thorn Trees
Spruce
Thousand head Kale Seed
Destroyed
Fine top Kohl Rabi
Destroyed
Poppy (Carnation Flowered)
Destroyed
Poppy (Paeony Flowered)
Destroyed
Nemophila Insignis
Destroyed
Nemophila Insignis
Destroyed
Limes
Spruce
Acer Maple
Acer Sycamore
Collinsia Bicolor
Partly destroyed
Gypsophila Elegans
Crop alright
Nemophila
Destroyed
Nemophila
Half destroyed
Ash Trees
Limes
Laburnum
Sycamore
Collinsia Bicolor
Partly destroyed
Candytuft
Damaged
Candytuft
Damaged
Limes
Candytuft
Crop undamaged
Roadway
Candytuft
Crop undamaged
Thorns
Limes
Seedling quicks
Seedling quicks
Myrobella fence
Entrance to Field
Myrobella fence
Quick Fence
Boundary Ditch

apparently gone here and also under the spruces in order to shelter from the sun. Some of the insects were feeding on a thistle under the spruces.

Leaves of cabbage and rhubarb were put down and on lifting them a few hours afterwards they were found to be entirely covered with the insects on the lower surface, as also were the leaves of the Abele Poplar which had blown from the tree.

The insects usually feed on the lower surface of the leaves at least in the sunlight. A few were found on the upper surface and on the edges. Many young plants were eaten off just above the ground level, *i.e.* through the portion of the stem below the seed leaves. On others (which were not eaten through) were obvious marks caused by the feeding of the beetles. Some of the leaves were damaged by having large holes eaten out of them and in others large pieces were eaten out of the sides of the leaves. They had eaten large holes through some of the cabbage and rhubarb leaves put down to trap them.

The damage was first noticed on May 13th and on May 14th 75 bushels of soot was spread over the attacked area measuring about two acres. This was followed by the application of 30 bushels of lime on May 15th. On May 16th a large number of the beetles were found dead. On June 17th large numbers of dead beetles were present over the attacked area whereas only an occasional live one was found. Cabbage leaves were put down on June 17th and on examining these only three beetles were found. The lime and soot seems to have been very successful in keeping down further attacks of this beetle.

In Fowler's *British Coleoptera* the following is given as the habitat of this beetle: "Sandy places; in moss, etc.; very local and, as a rule, rare, but occasionally in profusion."

It was thought from this that possibly the beetle was introduced by means of peat-moss manure, but on inquiry it was found that no straw manure was used.

I can give no explanation as regards the introduction of this beetle into the nursery which is otherwise comparatively free from insects.

F. R. PETHERBRIDGE,

Cambridge University.

SOME FEEDING HABITS OF SLUGS.

The connection of slugs and tapeworms has often been discussed. Some slugs serve as intermediate hosts for certain bird Cestodes (Grassi and Rovelli, 1892) and it has been suggested that they do the same for the Anoplocephaline Cestodes of ruminants and rodents although no convincing evidence has as yet been brought forward (Riehm 1881, Stiles 1893).

An examination into the habits and food of certain slugs made in connection with a research upon lamb tapeworm disease has brought out some interesting facts. The work was done at the Department for Agricultural Research in the University of Birmingham during the summer of 1914.

By the kind permission of their owners, fields were examined on which lambs infected with tapeworm were grazing (the worm commonly found in the Midlands is *Moniezia expansa*, the broad tapeworm of lambs). The fields were in the following localities: Bradley Green and Shurnock near Feckenham, Worcestershire; Oaklands, Allesley near Coventry; Wigmore Grange, Leintwardine, near Ludlow. The golf course at King's Norton near Birmingham was also examined. From the end of April until the end of June the ripe proglottides of this worm were to be found lying about on the fields. At Feckenham and Allesley rabbits were numerous in the same fields and were also infected by a tapeworm (*Cittotaenia pectinata*) and, although I never found the proglottides lying about, the eggs were on the field and could be seen by taking some grass, soaking it in water, and filtering it through cambric. On examining the filtrate the eggs were discovered.

Although *Moniezia* and *Cittotaenia* differ widely they belong to the same group of Taeniids, the Anoplocephalinae, and in all probability their life-histories are somewhat similar.

In these fields were always found two species of slug and only two—*Agriolimax agrestis* and *Arion circumscriptus*, the former very much more common than the latter. In the daytime they are both to be found at the roots of long grass, in holes with dead leaves or even buried in the ground if the season be dry. The habit of burying itself in the ground is very usual with *Arion circumscriptus* and not infrequently it is to be found lying amongst the lambs' faeces.

In the evening the slugs all come out and eat. They also emerge in the daytime after warm rain. It is evident that they are exceedingly

fond of the proglottides of *Moniezia*. I have shut both slugs up in boxes with the lambs' faeces containing proglottides and have always found that they devour the latter with avidity selecting them in preference to the other food. They also eat *Cittotaenia* in the same way.

On June 5th, 1914, twelve *Agriolimax agrestis* were collected and put in a small tin at night with several *Moniezia* proglottides. In the morning all had been eaten. On examining the faeces of the slugs they were found to contain numerous *Moniezia* eggs having apparently passed out with no alteration, some of the hexacanth embryos being still alive. Examination was made of the slugs at various intervals from two days to a month, by teasing up the tissues and by sections. In no case could any trace of a larval Cestode be discovered. Inside the alimentary canal were eggs, but only one was found with the pyriform apparatus free from its outer shell and the embryo itself was unaltered.

It is not only when there is nothing else to eat that the slugs eat the proglottides, for in a specimen of *Agriolimax agrestis* found on the fields at Leintwardine the stomach was full of *Moniezia* eggs.

It is the same with *Arion circumscriptus*. A specimen from Leintwardine also had its stomach full of eggs. One *Arion hortensis* was put in a box with grass and a piece of *Moniezia* consisting of ten proglottides. In half an hour at mid-day it had eaten the whole of this piece. Examination of its faeces showed the eggs unchanged and the embryos alive. The slug was sectionised and examined but no trace of development of the embryo was found. Other specimens gave similar results.

A large mass of *Moniezia* was found in a field at Lower Shuckburgh, Northants, and in it was a small *Arion circumscriptus*. It is evident that the slugs seek out *Moniezia* to eat it.

These slugs also eat *Cittotaenia* and are very fond of eating rabbits' faeces. Both of these species are to be found in the fields devouring the pellets, and their intestines are often full of the brown decaying vegetation from these. Two *Arion circumscriptus* took half an hour to eat one *Cittotaenia*-proglottis each, and four *Agriolimax agrestis* the same length of time.

Eggs of both species of slug were hatched in earthenware pots and the young fed with proglottides of *Moniezia* and *Cittotaenia*. These were examined at intervals but in no case could any development of the embryos be seen.

From these observations there is no evidence to show that *Agriolimax agrestis* and *Arion circumscriptus* act as intermediate hosts for *Moniezia expansa* and *Cittotaenia pectinata.* It was thought that possibly the eggs might undergo some alteration in the intestine which though not apparent might influence their development in other slugs. The slugs' faeces which were full of eggs were offered to other specimens of these slugs but in no case would they eat them.

It is clear that both slugs eat tapeworms on the field. May they not act much more as scavengers than we are in the habit of thinking and do far more good in these fields than we imagine? What is the reason of the abundance of such slugs in these fields? It is quite conceivable that they are there because of the abundance of this Cestode food of which they are so fond.

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NOTE ON THE REMARKABLE RETENTION OF VITALITY BY PROTOZOA FROM OLD STORED SOILS.

Introduction.

In the sample house at the Rothamsted Experimental Station, Harpenden, there is a remarkable collection of soils taken from the experimental plots at various times since the commencement of the famous work by Lawes and Gilbert in 1843. These samples have been stored in bottles the corks of which have been covered with leaden capsules and have thus been insured against the possibility of infection from dust. Many bottles have remained unopened since the day on which they were put up. The exact treatment to which the soils were submitted before being bottled is rather uncertain, but it seems

that they were spread out and allowed to become slightly air-dried so that they could be more easily sieved.

Large bottles capable of holding 200 ozs. were then filled with the soil which had been passed through a sieve having $\frac{1}{4}$ inch meshes. The degree of dryness of the soils varies considerably, some having about 3 per cent. or 5 per cent., others having from 10 to 15 per cent. of water by weight; the samples for any particular year however appear to be of about the same degree of dryness. In most cases the soil was taken from different depths at intervals of nine inches, sampling proceeding in some cases into the deep layers of the sub-soil.

Experiments.

It was my privilege whilst working at the Rothamsted laboratory to examine culturally soil from a few of these bottles for the presence of protozoa and only samples from the top nine inches of a plot were tested. In some preliminary experiments in 1912 it was found that Broadbalk soil bottled in 1846 revealed no protozoa in culture, but that Barnfield soil bottled in 1870 yielded amoebae and flagellates, and Agdell soil bottled in 1874 yielded amoebae and flagellates, and the ciliates *Colpoda steinii* and *Colpoda cucullus*, in hay-infusion cultures.

These results were very interesting as showing that the protozoa had retained their vitality probably in the encysted condition for a period of 42 years in the case of the Barnfield soil and 38 years in the Agdell soil.

As there were other bottles containing soil put up between 1846 and 1870, I decided to make cultures of some of these with a view to finding out the oldest soil from which protozoa could be obtained and the different species of protozoa which had survived.

Dr Russell, director of the laboratory, very kindly granted me permission to take small quantities of the soil from those bottles which I desired to test and I take this opportunity of thanking him for allowing me to make use of these valuable soils.

The following soils were tested for the presence of protozoa; Broadbalk 1856, Broadbalk 1865, Geescroft 1865, Agdell 1867, Hoosfield 1868, and Barnfield 1870. From all the cultures except those of Broadbalk 1856 protozoa were obtained. The cultures were made in small glass dishes under the usual bacteriological precautions of sterile media and vessels, etc., so that there can be no doubt that the organisms encountered really came from the soil and not from air-borne dust particles by chance infection.

As a culture medium, saline egg-albumen consisting of 5 per cent. NaCl solution 100 c.c., white of new-laid egg 15 c.c. was used.

Film preparations were made by floating cover-slips on the surface or by placing them at the bottom of the cultures. The films thus obtained were usually fixed in Maier's solution and stained with iron-haematoxylin.

It is not the purpose of this paper to go into details concerning the different species of protozoa found, but especially to put on record the remarkable fact of the survival of protozoa for practically 50 years under conditions precluding the possibility of trophic existence.

The following protozoa have been identified. The list does not include all the forms encountered, for there are a few which I have not been able to classify satisfactorily yet.

Amoebae belonging to the *limax* group were obtained from all the soils which yielded protozoa. I have made observations on the mode of nuclear division in three of these with the result that all three appear to be new species. One of them seems to be very closely related to *Amoeba glebae*[1] Dobell. Flagellates: *Monas termo*, *Cercomonas crassicauda*, *Cercomonas longicauda*, *Bodo* (*Prowazekia*) *saltans*, *Bodo ovatus*? and *Tetramitus spiralis*, nov. spec.

In addition to the above I have obtained a rather remarkable organism which undoubtedly belongs to the genus *Spironema* Klebs[2]. Klebs obtained his examples from ditch-water on only two or three occasions and considered that they showed affinities with ciliates and flagellates, forming perhaps a sort of connecting link between these two groups. He did not, however, find out anything about the nucleus.

I have succeeded in making out the nucleus which, though peculiar, exhibits flagellate rather than ciliate affinities.

Historical.

It may be of interest, in view of the great length of time which the resting cysts of these protozoa have retained their vitality, to state briefly the previous records of similar phenomena.

According to Butschli[3], Meunier (1865) saw *Colpoda* emerge from cysts dried for fourteen months. Balbiani (1881) kept a slide with

[1] "Cytological Studies on three species of Amoeba, etc." *Archiv f. Protisten.* Bd. 34 (1914), p. 139.

[2] *Flagellatenstudien I. Zeitschr. f. wiss. Zool.* LV (1892), p. 350.

[3] Bronn's *Thierreichs* 1, Abth. III, p. 1663.

Colpoda cysts on it for seven years and resuscitated the organism each year by moistening the slide; they afterwards encysted. I think that this can scarcely be considered as a case of retained vitality for seven years, for the *Colpoda* obtained a new lease of life each year when the slide was moistened. Nussbaum found cysts of *Gastrostyla vorax* capable of living after two years and Maupas saw *Gastrostyla steinii* cyst after twenty-two months drying in a watch-glass.

These records refer to ciliates only and the longest period of retained vitality, excluding Balbiani's results with *Colpoda* for reasons given above, is two years. I have shown above that two species of *Colpoda* have retained their vitality for 38 years.

I cannot find any reference to early work on these lines in the case of flagellates and amoebae. Quite recently however Noc[1] has published a short paper dealing with latent life in protozoa. Some tubes containing a little water and various protozoa were hermetically sealed in 1908 and recently opened. There was no trace of anything but encysted amoebae, some of which revived after ten days or more. This proves survival for six years. A minute flagellate *Oikomonas termo* was obtained from some rough Tonkin paper after desiccation for five years.

The retention of vitality for a period of forty-nine years which I have recorded above shows that protozoa can survive in an encysted condition for a much longer time than was known from previous records.

I deal with the significance of these results in relation to the hypothesis of protozoa acting as a limiting factor on soil bacteria in another paper which I hope to publish very soon. A further paper embodying the cytological work on the organisms obtained from these old soils with descriptions of new species is also being prepared.

In conclusion I desire to express my thanks to Prof. F. W. Gamble, director of this laboratory, who suggested, about three years ago, the desirability of examining samples of old stored soils for the presence of protozoa.

POSTSCRIPT.

Immediately after submitting the foregoing for publication I obtained access to Noc's paper[2], only the abstract of which I had been

[1] Noc, F., *C. R. Soc. Biol. Paris*, LXXVI (1914), pp. 166–8. *Abst. Jour. Roy. Mic. Soc.* 1914, pt. 3, p. 267.

[2] "Sur la durée de conservation de Protozoaires à l'état humide ou desséché" (*C. R. Soc. Biol. Paris*, LXXVI (1914), p. 166).

able to see earlier. In it he speaks of the results obtained by Certes who found that various infusoria, flagellates, and amoebae could be revived after five or six years only from the sediments on which he worked, whilst only *Colpoda* remained capable of revival after thirteen years of storage.

A reference is also given to a paper by Fauré-Frémiet[1] on a ciliate *Mycterothrix.* On looking this up I find that it records that Balbiani working with desiccated material containing cysts of *Mycterothrix* was able to revive the organisms by moistening after keeping the material dry for four years.

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NOTES ON A SCALE INSECT ATTACKING CACAO IN UGANDA.

In 1909 a scale insect attacking cacao appeared in the Botanic Gardens. Specimens of this new pest were submitted for identification to Prof. Newstead, who described it as a new species, *Stictococcus dimorphus* Newst.[2].

The other food plants on which it has been collected by the writer are mulberry, *Markhamia platycalyx*, ornamental Hibiscus, *Anona muricata, Croton tiglium*, guava and *Cajanus indicus*. With the exception of *M. platycalyx*, all of these plants have been introduced, which, together with the fact that this Coccid has been found in the depths of a forest of something like 180 square miles on *M. platycalyx*, is conclusive evidence that it is indigenous and that it spread from that plant to the others.

From my observations cacao appears to be the favourite food plant. When the varieties of cacao, *foresteiro* and *creolle*, are grown side by side, the infestation on the former is invariably the most serious. The infestation on cacao is always restricted to the pods and stems of the pods, never having been found on the foliage or branches. (Fig. 1.)

[1] "Le *Mycterothrix tuamotuensis* (*Trichorhynchus tuamotuensis*) Balbiani." (*Arch. f. Protist.* xx, p. 223, 1910.)

[2] Newstead, *Bulletin Entomological Research*, vol. I, p. 63, f. 2 (1910); Green, *l.c.*, p. 201 (1910).

Treatment. This is not readily killed by insecticides at the usual strengths; but, fortunately, on account of its always being located on the pods, insecticides can be used at greater strengths than they could be applied to the foliage in this country, where the trees are never dormant and where for some reason, probably altitude, oils applied at the usual strengths are most apt to "burn" the foliage.

I have experimented with a large number of contact poisons with the result that I favour the use of whale oil soap and soft soap-kerosene emulsion. The results of some of the experiments are tabulated below.

Spraying Experiments against the Cacao Scale, St. dimorphus Newst.

			First examination			Second examination			Third examination		
Experiment number	Treatment	Number of pods treated	Number of scales examined	Number of scales dead	Percentage of dead scales	Number of scales examined	Number of scales dead	Percentage of dead scales	Number of scales examined	Number of scales dead	Percentage of dead scales
1	Whale oil soap	8	300	288	96·0	300	281	93·6	300	285	95·0
2	Kerosene emulsion	8	300	226	75·3	300	214	71·3	300	210	70·0
3	Carbolic acid emulsion ..	10	500	242	44·4	500	251	50·2	500	205	41·0
4	Resin-soda wash	8	300	83	27·7	300	99	33·0	300	78	26·0
5	Lime-sulphur wash	12	500	491	98·2	500	436	87·2	500	401	80·2
6	Kerosene-lysol emulsion ..	12	500	268	53·6	500	261	52·5	500	274	54·8
7	Soft soap-kerosene wash ..	12	500	482	96·4	500	469	93·8	500	456	91·2
8	Check	—	300	23	7·7	300	17	5·7	300	28	9·3

Experiment 1 was sprayed with whale oil soap, 1 lb. to 4 gallons of water.

Experiment 2. The formula of the stock solution of kerosene emulsion was:

Kerosene	2 gals.
Soap, hard	$\frac{1}{2}$ lb.
Water, hot	1 gal.

The stock solution was diluted to a 20 per cent. spray, *i.e.* 1 gallon of the stock solution was diluted with $2\frac{1}{3}$ gallons of water.

Experiment 3. The stock solution of carbolic acid emulsion was made according to the formula:

Soap, hard	1 lb.
Water	1 gal.
Carbolic acid, crude	1 pt.

One part of this solution was diluted with 30 parts of water.

Photo by T. D. Maitland

Fig. 1. A typical infestation of a pod of *Cacao theobromae* var. *forestiero*, with *Stictococcus dimorphus* Newst.

Experiment 4. The formula of the resin-soda wash was:

Soda, caustic	3 lbs.
Resin	10 lbs.
Fish oil	$\frac{3}{4}$ lb.
Water	25 gals.

Experiment 5. The stock solution of lime-sulphur wash was made according to the formula:

Lime, unslaked	20 lbs.
Sulphur, flowers of	15 lbs.
Water	50 gals.

and this was diluted to 85 gallons.

Experiment 6. Kerosene-lysol emulsion was made by emulsifying:

Lysol	3 ozs.
Kerosene	9 ozs.
Water	4 gals.

Experiment 7. The soft soap-kerosene wash was made by boiling together 8 lbs. of soft soap and 5 gallons of kerosene. On cooling this becomes a jelly, 10 lbs. of which was added to 30 gallons of water for use.

Experiment 8. For the purpose of comparison eight untreated pods were examined.

Natural enemies. I have frequently bred the Noctuid, *Eublemma costimacula* Saalm., of the subfamily *Erastriinae,* from this scale insect. During the examination of the pods treated with the above-mentioned sprays for dead insects several larvae of this moth parasite were found.

At a distance I have observed the bird, *Melanopteryx nigerrima,* picking at a cacao pod infested with this scale insect, but I could not be certain whether it was feeding on the scale insect or on the ants which accompany the scale insect.

The other local representatives of the genus *Stictococcus* are the species recently discovered by the writer, *St. formicarius* Newst., and *St. gowdeyi* Newst.[1] The former attacks a species of *Ficus,* and the latter *Harrogania madagascarensis* and coffee.

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[1] Newstead, *Bulletin of Entomological Research,* vol. IV, p. 70, f. 4 (1913).

REVIEW.

STEBBING, E. P. *Indian Forest Insects of Economic Importance. Coleoptera.* London, Eyre and Spottiswoode, Ltd., 1914, pp. xvi + 648, Plates I–LXIII and 401 text-figures.

THE author of this work was formerly a divisional forest officer in India who all through his career has devoted much of his energies to entomology. It redounds to his credit that he urged the importance of forest entomology in the eyes of the government of India, and in this way did much towards securing the creation of an official post to deal with the subject. In the year 1900 the office of Forest Entomologist was established for a period of two years, and Mr Stebbing appointed the first incumbent thereof. In 1904 the post was resanctioned, while in 1906 it was merged into the new appointment of Forest Zoologist. Mr Stebbing was also the first official Forest Zoologist to the government of India. During his tenure of these appointments he has produced a large amount of matter dealing with forest insects. Published for the most part in sources not easily available to entomologists, many of Mr Stebbing's writings are little known outside India, and have seldom had the advantage of scientific criticism. Observers in India are so few and far between that little has yet been done towards confirming or extending Mr Stebbing's work. On his departure from India he took upon himself the no light task of compiling the book before us. Without hesitation it may be said that it is the best piece of work Mr Stebbing has yet produced. Being free from almost all the errors and faults which marred his previous text-book of Indian Forest Zoology, we congratulate him on having written a very readable and excellently arranged book. Notwithstanding the title on its outside cover, the volume is limited to forest Coleoptera, and in confining his remarks to this single order of insects Mr Stebbing has exercised a wise decision. To have included the remaining orders would have savoured of indiscretion in view of the scanty state of our knowledge of Indian forest insects.

In his Preface Mr Stebbing has been generous to all who have helped him in any way. From Inspectors-General of Forests and the Lieut.-Governor of a Province down to the toiling camp clerk, acknowledgments are freely made. We do not ever remember having seen quite such an array of names in any book before.

Chapters I–IV are devoted to general remarks on the distribution of insects in the Indian forests, on injurious and beneficial species, remedial and preventive measures and other problems.

Chapter V consists of a brief introduction to the Coleoptera. We think, however, that the all-important section dealing with Coleopterous larvae might have been greatly extended to advantage. References to the works of Schiodte, Chapuis and Candeze, Perris, Rupertsberger and others would have acquainted the reader with the sources to which he must eventually turn for information concerning life-histories. The greater part of the book is occupied with an account of the forest Coleoptera arranged in systematic order and extending to over 560 pages. All the principal species known to the author are figured, and a brief description of each is given. Wherever information is available remarks on the injury they commit are made, which are usually supplemented by really excellent photographic plates. Here and there short descriptions of the larvae and pupae of various species are to be found. These descriptions, however, in most cases are too brief and vague to enable one to determine a particular larva with any degree of certainty. To merely describe, for instance, the pupa of *Cyrtotrachelus longipes* as being white and of the ordinary weevil shape, really does not help very much. Neither can we recognise the larva of *Sphenoptera cupriventris* when it is simply stated to be yellowish white with stout black mandibles, and the prothoracic segment broader than any of the segments behind it. In fact most Buprestid larvae may be said to agree with that description. One of the best life-histories in the whole book is that of the Longicorn *Hoplocerambyx spinicornis*, concerning which a good deal of useful information is brought to light by Mr Stebbing. It is not, however, absent from the Sal forests of the United Provinces as he believes. Perhaps the most interesting of the insects found by Mr Stebbing are the predaceous beetles of the genus *Niponius*. Although usually placed in the family Histeridae, there is something to be said for elevating them into a family of their own. So far, we know nothing of the larva of *Niponius* beyond what Mr Stebbing can tell us. If he can be constrained to publish an illustrated account thereof, it will not

fail to be of great interest to the Coleopterist as well as being of economic value.

The Scolytidae (Ipidae) are treated the fullest of any of the families, some 150 pages being devoted to them. The author has brought to light many species, some of them very obscure and easily overlooked. It is, however, hard to recognise some of Mr Stebbing's species from his descriptions. The writer of this review has devoted many hours over *Tomicus* (*Ips.*) *longifolia* and *T. ribbentropi* without being able to separate the one from the other. The same may be said with regard to certain of his *Polygraphus* and other species. In view of their great economic importance, the Indian Scolytidae are badly in need of revision. The government of India would do well to issue a monograph of all known Indian species with detailed figures, exhibiting beyond any possibility of doubt the diagnostic characters in each case. The monographs of Dr Hopkins in America would serve as an admirable model to emulate. In the Scolytidae closely allied species often exhibit dissimilar habits, and it becomes a matter of the greatest importance to name any particular species with certainty. In no other group of forest insects, that we are acquainted with, does the work of forest protection depend so much upon accurate specific determinations as in the Scolytidae.

We would impress upon the author that it is neither necessary nor desirable to describe new species in a general text-book of this description. We find that Mr Stebbing appears to have done so in more than a dozen instances. Furthermore to designate already described species as "sp. nov." is contrary to all recognised procedure. The expression "sp. nov." in such cases is highly misleading; for instance on p. 621 the reader would at first sight conclude that "*Platypus suffodiens* Sampson, sp. nov." is a new species described immediately below by Sampson. On the contrary the reference is given to the *Ann. Mag. Nat. Hist.* for 1913 where the original description is to be found.

Notwithstanding the points over which we disagree with the author, we think that the book will prove a distinct stimulus to Indian forest entomology. Most of the divisional forest officers, scattered through the length and breadth of the Indian Empire, are familiar with one or other form of destructive insect life in the lands under their charge. With the aid of this book perhaps some of them may be tempted to make a more serious study of the subject, or by collecting specimens and information help others to extend the boundaries of our knowledge of a wide and little explored field.

In conclusion we may add that the general "get up" of the book is admirable, and reflects the greatest credit on all concerned with its production. The majority of the plates are of a high standard of excellence and the same may be said of many of the text-figures. Exception, however, must be taken to figures 30 *d*, 65, 96, 107, 125, 138, 150, 154, 157, 159, 200, 291, 305, 324, and 385—also to Plate XV, figs. *a* and *a′*, and Plate XXXVI, fig. 2, all of which bear but little resemblance to the objects they are intended to represent. The paper and type utilised leave nothing to be desired, and we have noticed an almost complete absence of misprints.

A. D. I.

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